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FINAL REPORT

Evaluation of an Interactive Electronic NATOPS (IE-NATOPS) and Associated Graphic Interaction Concepts

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13. ABSTRACT *(Maximum 200 words)*
This report presents the results of a benchmark evaluation of a prototype design for an Interactive Electronic NATOPS (IE-NATOPS) to support Navy aircrews. An investigation was conducted to identify aircrew information requirements for decision making associated with monitoring of aircraft system health and management of in-flight mechanical malfunctions. It was determined in two simulator-based studies with H-46 aircrews that various types of aiding in support of mechanical (and other subsystem) health monitoring and problem diagnosis are desirable and feasible, but such information must be fully integrated into the Navy helicopter NATOPS flight manual and checklists that represent training doctrine for aircraft operations. The IE-NATOPS concept is to provide the pilot in the cockpit with a computer-based presentation of the information in hard-copy manuals, providing operating information and aircraft-specific procedures. For military and commercial aviation applications, the benefits are compelling - context sensitivity, fast and cheap "updatability", and the capacity for embedded intelligence and embedded intelligent training. A prototype IE-NATOPS was developed for the SH-60F helicopter. Multiple options are under consideration for implementation of IE-NATOPS in the cockpit, including via an "electronic kneeboard" system that would interface with other aircraft information and alerting systems.

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Executive Summary

This report presents the results of a benchmark evaluation of a prototype design for an Interactive Electronic NATOPS (IE-NATOPS) to support Navy aircrews. The IE-NATOPS design was developed following an investigation of aircrew information requirements for decision making associated with monitoring of aircraft system health and management of in-flight mechanical malfunctions. It was determined in two simulator-based studies with H-46 aircrews that various types of aiding in support of mechanical (and other subsystem) health monitoring and problem diagnosis are both desirable and feasible, but that such information must be fully integrated into the Navy helicopter NATOPS flight manual and applicable checklists that represent training doctrine for aircraft operations and are used by aircrews during normal and emergency in-flight operations. The baseline concept for IE-NATOPS is to provide the pilot in the cockpit with a computer-based presentation of the information that is currently provided in hard-copy manuals, providing operating information and procedures that are specific to each Navy aircraft. For the Navy, as well as for virtually all other military and commercial aviation applications, the benefits are compelling – context sensitivity, fast and cheap "updatability", and the capacity for embedded intelligence and embedded intelligent training. Initial research efforts in this program focused on the H-46 helicopter, but later developments were for the SH-60F. Multiple options are under consideration for implementation of IE-NATOPS in the cockpit, including via an "electronic kneeboard" system that would interface with other aircraft information and alerting systems.

The approach to design of IE-NATOPS involved the development of a design specification, production of a prototype demonstration, and the identification and evaluation of Navy institutional integration issues. The design specification focused on:

- aircrew access during an emergency with automatic triggering,
- aircrew access during an emergency based on aircrew initiative and problem identification,
- aircrew access during non-emergency periods, and
- aircrew access to automatic and interactive performance data calculations.

The design specification was based on interviews with experienced Navy aircrews regarding the concept of an IE-NATOPS with specific reference to the Navy SH-60F helicopter. Based on those interviews and an analysis of aircrew information needs, a design specification was formulated addressing both event-triggered needs and aircrew initiative information needs. Six modes of IE-NATOPS functionality were defined: Pilot Checklists (PCL), NATOPS tutorial text and graphics, performance data, alerts, trends, and notes. Specific IE-NATOPS design features were derived from analyses of the current NATOPS organization to identify the Parts, Chapters, Sections, and sub-Sections that are used most by the aircrew in the cockpit, and to suggest potential design features for an effective interface structure.

An experimental evaluation was performed to compare aircrew performance when using the traditional paper copy of NATOPS and the associated Pocket Check List (PCL) with

that of the IE-NATOPS system. This evaluation effort attempted to establish whether or not there are notable differences in resolving problem situations dependent upon the format of the NATOPS and PCL used. Major findings of this study demonstrated that the average response time for training scenarios using the electronic version of NATOPS was significantly faster than the average response time using the paper version. Since the training scenarios focused on pure access time to specific information, this is indicative of a strong advantage of IE-NATOPS over the paper version when explicit instructions are given as to the location of specific NATOPS information. In other experimental trials, more self-directed problem solving and decision-making were required to determine the path to the required information and, not surprisingly, the comparison of IE-NATOPS versus hard-copy performance varied considerably with problem characteristics. Overall, however, there were no significant differences in response time between electronic and paper versions of NATOPS for the self-directed scenarios. Given that the aviators who participated in this benchmark evaluation of the IE-NATOPS had less than an hour of training on IE-NATOPS, and given that the aviators were highly experienced in the use of the paper NATOPS and PCL for accessing information to resolve problem scenarios, the results from the problem solving trials are indicative of a system that may prove through further training and experience to be superior to the existing method of accessing hard-copy NATOPS data in the aircraft.

Since several types of NATOPS information involves graphic presentation and since graphic displays can be awkward on the kind of small-screen devices envisioned for IE-NATOPS, several graphic interaction methodologies were formulated and investigated to support IE-NATOPS graphics requirements. Graphic interaction concepts that were investigated include an "electronic magnifying glass," highlighting of axis lines and parameter curves, and dynamic labeling. Illustrative applications were made in the context of a typical aircraft performance chart as well as for a wind envelope chart. These alternative concepts for interacting with NATOPS charts were simply presented to the participating pilots and feedback was solicited on each of the concepts. In general, the results of the interviews suggested that pilots felt the techniques used when interacting with graphics are very important to the usefulness of the IE-NATOPS system. Due to the small size of the targeted IE-NATOPS display, pilots felt that the ways in which they interacted with graphics in the paper NATOPS manual would not be adequate when a performance chart was reduced in size. More specifically, every pilot felt that the best, and most useful, concept was dynamic labeling. They felt that this type of display provided them with all of the values that are of interest when they are interacting with a performance chart. Each pilot liked the fact that all important parameters are quickly available and felt that the feedback provided to them through the use of highlighting and labeling would allow them to immediately determine the particular value for which they were looking. However, some pilots felt that it was unnecessary to highlight the entire parameter curve. Some suggested that the value of the parameter simply be displayed off the tip of the stylus to limit the spread of information within the display.

IE-NATOPS can offer several significant benefits over hard-copy checklists and flight manuals for the Navy helicopter aircrew. It can provide for rapid access to emergency procedures by the aircrew, both via automatic alerting (i.e., through an automatic

diagnostic system) and via manual search by the aircrew. It can also provide an efficient mechanism to facilitate Navy control of NATOPS revisions, since the electronic implementation will afford the opportunity for rapid, inexpensive dissemination of document revisions. In order to achieve these benefits, it is necessary to insure that the product is effectively usable in all relevant aspects (e.g., accessible to all aircrew, searchable with all relevant strategies, readable in all conditions, etc.). This effort has developed an interface design that illustrates how each of the access modes can be effectively supported.

IE-NATOPS has potential uses not only as a decision-aid while in the cockpit, but also as a training tool that can be implemented in support of current NATOPS training procedures. Because the tool is electronic, it offers a portable training mode as well as a method to support delivery of training via the design of event-based scenarios in which specific competencies dealing with IE-NATOPS are targeted. This would allow targeted practice and feedback to be built into the system to augment the feedback given by the instructor(s). To pursue such training applications, a targeted analysis could be conducted of current NATOPS training procedures to: (a) identify strengths and weaknesses of the current method, (b) determine where IE-NATOPS may fit into the training rotation, and (c) identify the competencies that should be addressed with this tool.

Further IE-NATOPS development efforts are envisioned in both operational development and research. Operational development must be conducted to resolve issues in the areas of institutionalization, aircraft integration, and interface design. Institutionalization issues will include coordination with NATOPS committee members and the Naval Air Systems Command program office for training systems (PMA 205) to identify concept issues related to training and to integration of IE-NATOPS into the NATOPS creation and update process. Flight evaluations of a certified IE-NATOPS system will be required to address aircraft integration and interface design issues. Future research efforts will be required to refine diagnosis logic for cockpit alerting and tools to interact with graphics on small screens. Research is also warranted to investigate alternative tools for performance data calculations and checklist interface features.

1. Introduction

1.1 Background

Navy aircraft pilots and aircrews are guided in their in-flight decision processes by the Naval Air Training and Operating Procedures Standards (NATOPS) manuals, which provide text descriptions of systems, tactics, responsibilities, and equipment usage protocols, as well as checklists and graphic aids for calculation of aircraft performance data. In the present project, an interactive electronic NATOPS (IE-NATOPS) has been developed to facilitate the in-flight decision-making processes requiring NATOPS data. By making human-centered improvements to the organization, presentation, and accessibility of the NATOPS data, it is anticipated that more timely resolution of systems and performance related problems occurring in flight may result than is observed with the current paper-based NATOPS format (Degani & Wiener, 1990).

Before designing IE-NATOPS, aircrew information requirements in the area of aircraft health management were investigated through a series of two empirical studies with naval helicopter pilots. Both studies were conducted with H-46 aircrews at Naval Air Station North Island using a motion-base simulator in order to:

- determine procedures currently used by aircrew in mitigating in-flight mechanical systems emergencies,
- determine the decision processes employed by aircrew in resolving these emergencies,
- gather aircrew evaluations of emerging mechanical fault diagnostic technologies, and
- determine how information available from emerging mechanical diagnostic systems could best be displayed to aircrew to predict and mitigate these emergencies.

The purpose of the first information requirements study was to conduct systematic interviews with flight crews regarding their current procedures for in-flight mechanical system emergencies (Glenn et al., 1998; Deaton et al., 1997 a & b). The study assessed cognitive activities expected to be important when responding to mechanical emergencies, and the attention devoted to each activity. A secondary goal of the first study was to identify the information requirements of a new diagnostic system to be used to predict and mitigate in-flight mechanical system emergencies. The study represented a first step towards identifying the information requirements of aircrew in determining the status of aircraft mechanical systems using advanced sensor and processing technology.

Other research efforts in this program addressed the development of techniques and assessment of general technological feasibility for generating various kinds of information to aids for mechanical system health monitoring and diagnosis. Since these efforts are only tangentially relevant to the IE-NATOPS design that is the focus of this report, they will not be further discussed here; rather the interested reader is referred to Byington et al. (1999) for a general overview of the kinds of information envisioned, to Garga et al. (2001) for an approach to an automated reasoning technique for this purpose, and to Campbell et al. (2001) for a description of specific diagnostic algorithms based on

mechanical equipment vibration spectra. The experimental designs for both of our information requirements studies were based on these assessments and projects for the near-term feasibility of obtaining the various kinds of aiding information that were predicated in these studies.

As reported in Glenn et al. (1998) and Deaton et al. (1997 a & b), the emphasis in the first study was to use survey techniques to assess aircrews' use of information, potential sources of workload, and the utility of diagnostic systems. A key finding of that study was the need for a system that could diagnose mechanical problems and assess the impact of those problems on a mission. Aircrews also requested a diagnostic system that could provide action recommendations to help complete a mission. Figure 1 presents the frequencies with which aircrews indicated interest in various categories of information during simulated emergencies. Results are included for both the questionnaire and from an analysis of actual aircrew communication during a simulated mission.

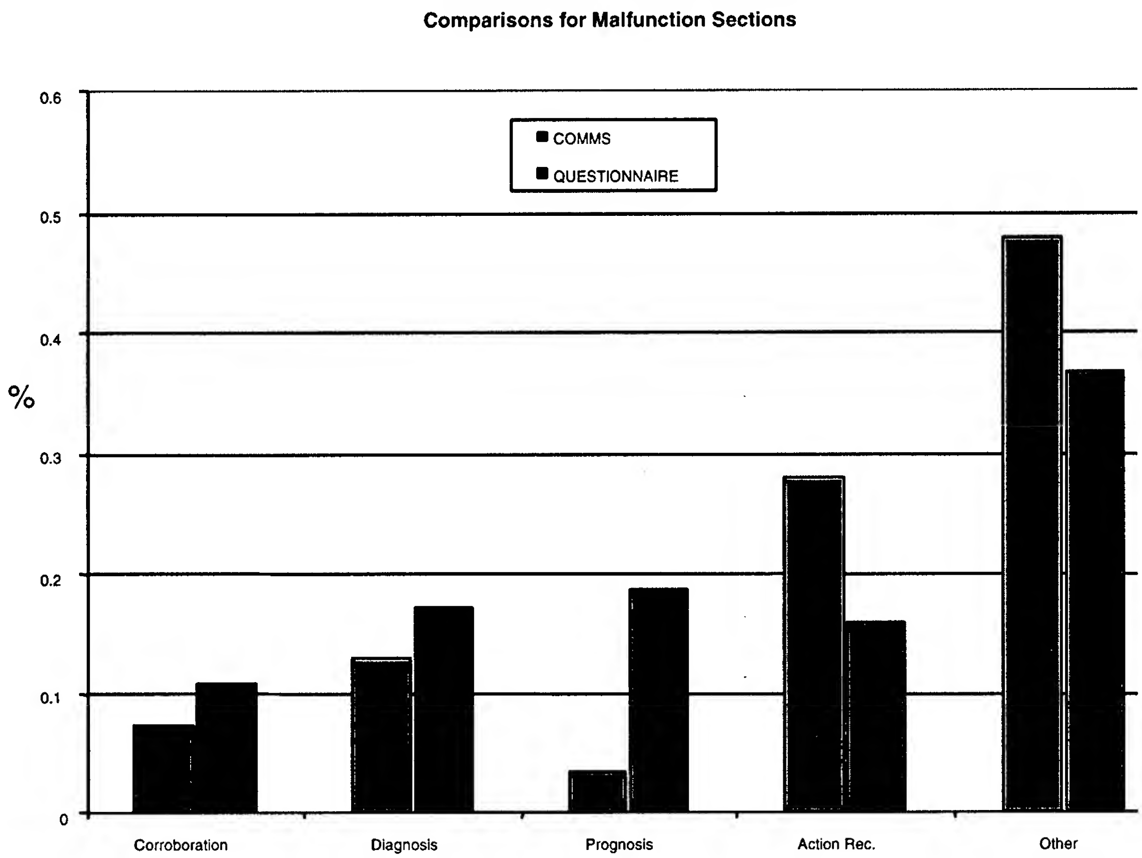

Figure 1. Information Requirements Study 1 Results

The second information requirements study was designed to assess the usefulness of various kinds of information relevant to mechanical fault management (see Byington et al., 1999). Accordingly, it explored the feasibility and potential benefit of new technologies to help aircrews in mechanical fault management. More specifically, the purpose of this study was twofold:

(1) to evaluate the value that various kinds of information have on the ability of the aircrew to successfully manage in-flight mechanical faults, and
(2) to demonstrate an initial notational interface concept and explore its potential benefits to the aircrew.

This second study built upon the foundation established by the first study, used the results of that study to develop a prototype user interface for the diagnostic system, and assessed that diagnostic system and user interface in helicopter operations. The goal was to determine the merits of aiding the aircrew with an automated diagnostic system when compared to the current, unaided situation.

The approach was successful in identifying a number of important factors that can significantly influence the development of this kind of aiding technology, as well as raise general issues for consideration in the development of cockpit automation technology. First, the results clearly indicated that automated technologies can enhance aircrew performance when correctly designed, improving aircrew ability to diagnose true failure conditions and recognize false alarms. Second, the potential utility of certain types of information (and the type of aiding that information implies) was revealed, with pilots indicating primary interest (as measured by screen dwell time) in the 'analysis' category of information, as seen in Figure 2. In addition, the results showed differences in information requirements based on crew position. Third, aircrews were unanimous in their desire to have an electronic NATOPS as a means to access and to display emergency procedures. Fourth, the communication data indicated an insignificant effect of the automated diagnostic system on communication content or frequency, which implies that the technology does not significantly alter crew workload or crew coordination requirements as discussed in Bowers et al. (1995).

1.2 Design of IE-NATOPS

Design of IE-NATOPS focused on several issues:

- aircrew access during an emergency with automatic triggering,
- aircrew access during an emergency based on aircrew initiative and problem identification,
- aircrew access during non-emergency periods, and
- aircrew access to automatic and interactive performance data calculations.

The first step taken to develop the design specification was to interview experienced Navy aircrews regarding the concept of an IE-NATOPS with specific reference to the Navy's emerging CH-60S and SH-60R aircraft. Based on those interviews and an analysis of aircrew information needs, a design specification was formulated addressing both event-triggered needs and aircrew initiative information needs. Six modes of IE-NATOPS functionality were defined: checklists, NATOPS text and graphics, performance data, alerts, trends, and notes. Only the first four modes will be discussed in this paper since they are essential functions that are in current development, while assessments of the other functions (trends and notes) are being postponed pending design refinements.

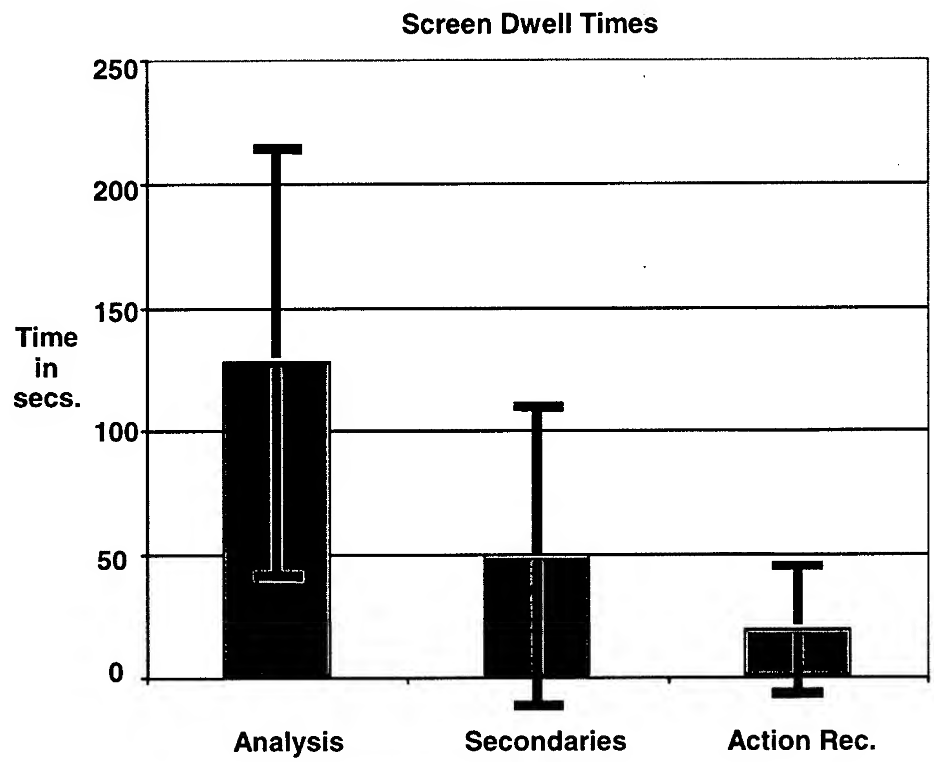

Figure 2. Study 2 Results

1.2.1 Initial Design

The initial analysis focused on the SH60B NATOPS Flight Manual and associated pocket checklists and more recently on the SH-60F variant of the same information. The goal of the analysis was to review the overall structure of the NATOPS outline, identify the Parts, Chapters, Sections, and Sub-Sections that are used most by the aircrew in the cockpit, and to suggest potential design features for an effective interface structure. Where possible, Parts, Chapters, and Sections were combined under more general categories to streamline the overall NATOPS outline. This streamlining was necessary to minimize the number of potential selections on the interface. For example, categories that deal with aircrew requirements, training, and evaluation (i.e., Indoctrination, Aircrew Coordination, and NATOPS Evaluation) were combined under an "Aircrew Management" category. Care was taken to ensure the contents of the NATOPS were not changed. The outline structure of the NATOPS main body (i.e., Chapters, Sections, and Sub-Sections) remained unchanged and became the model for the breakdown structure of the information for the interface and the paths the aircrew can use when navigating through the information. Using MIL-STD-1472F, buttons, text fonts, color and the overall design of the interface screens were developed and presented in the form of storyboards.

Included in the documentation analysis was a detailed analysis of the aircraft performance charts. This analysis was conducted to determine requirements for screen design and aircrew interaction. Each chart was reviewed to identify the particular

function it performed and to determine what information it required and what information it produced.

The NATOPS analysis was conducted to develop an interface design that would not conflict with the current structure of the manual. The first goal of this analysis was to identify the information that would be used most frequently by the aircrews in the cockpit. After a review of the categories outlined in the manual, it was determined that Normal Procedures, Emergency Procedures, Performance Data, and All-Weather Procedures were required and that the remaining "Parts" of the document could be consolidated to limit the number of category selections incorporated in the interface. As shown in Figure 3, the required categories of information were maintained, and the categories that are common knowledge to aircrews (i.e., system descriptions, aircraft flight characteristics, training, aircrew requirements, etc.) were consolidated under the new categories shown in the two boxes on the left.

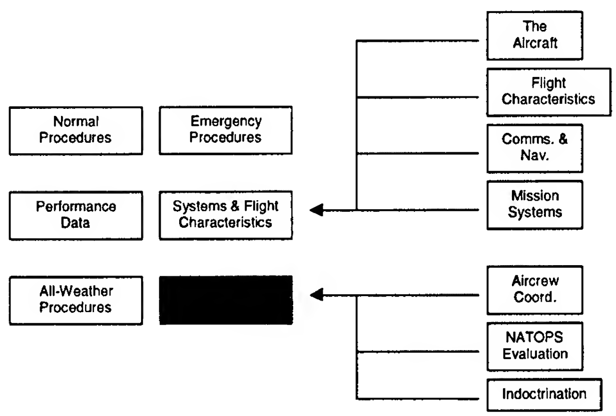

Figure 3. Required Categories of Information

The resulting six categories were incorporated into the interface design as the options on the NATOPS Main Menu (see Figure 4).

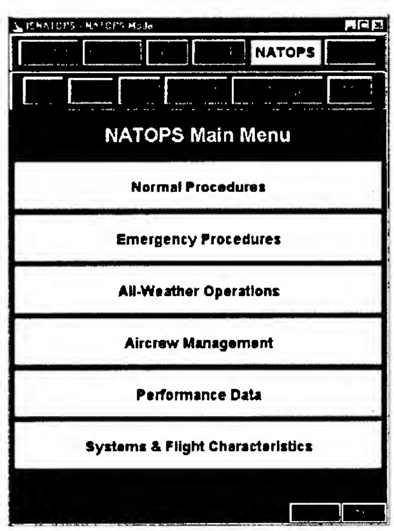

Figure 4. IE-NATOPS Main Menu

A second goal of the NATOPS analysis was to develop an information structure for the interface to promote user acceptance. We concluded that the current outline structure of the NATOPS manual should be maintained and used as the information structure for the interface. It is important to maintain aircrew familiarity with the information in the document because any change to the current outline structure will make the information less familiar and greatly reduce aircrew acceptance of the system. Therefore, the Chapter, Section, and Sub-Section titles were used as the structure by which the aircrew navigated through the information. Knowing the basic information that each screen must display, it was then necessary to develop information selection paths that provide aircrews with the needed information with the least amount of button selection. Once the information selection paths were identified, screen designs were then developed. Figures 5 through 7 provide examples of the results of this effort. Figure 5 is the screen that is displayed when the aircrew selects the Normal Procedures button on the NATOPS Main Menu.

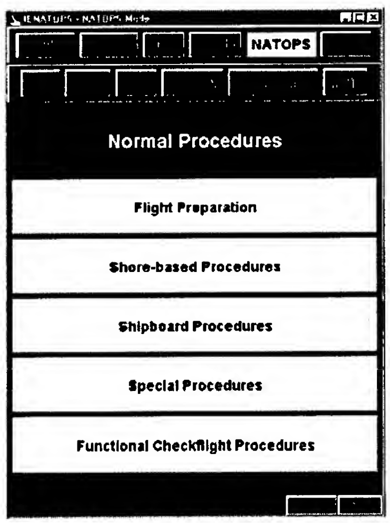

Figure 5. IE-NATOPS Normal Procedures Menu

In the Normal Procedures menu (Figure 5.), the aircrew can select the desired NATOPS chapter that will display a menu (represented as a tree hierarchy as shown in Figure 6) listing all subsections of the chapter.

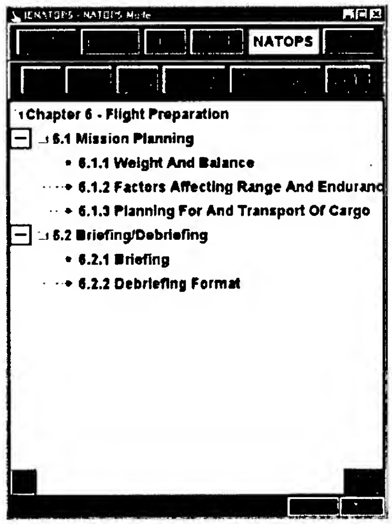

Figure 6. Flight Preparation Menu Tree

From the menu tree in Figure 6, the aircrew has the choice of selecting the desired NATOPS section, using the navigation button (i.e., Back, Forward, History, etc.), or choosing another mode. Figure 7 shows the screen that will be displayed when the aircrew selects a specific subsection. Alternatively, the user can follow a similar path through the hierarchy of checklist mode menus to access individual checklist procedures (Figure 8).

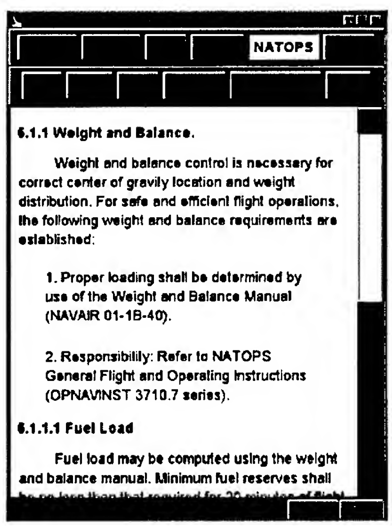

Figure 7. NATOPS Text Screen

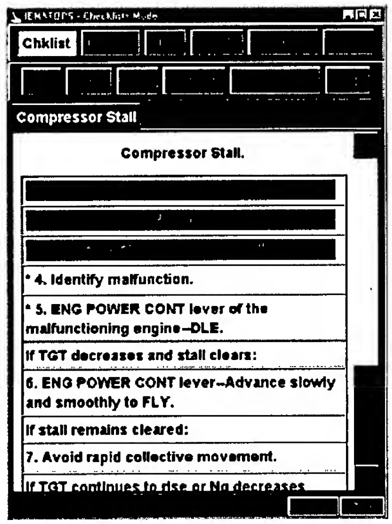

Figure 8. Checklist Text Screen

As shown in Figures 4 through 8, the basic design concept provides a quick and efficient method of navigating through NATOPS and checklist information. When dealing with performance data, however, additional dynamic interactive capabilities are needed, thus, requiring a different design concept. Figure 9 illustrates the screen design that was developed for the "Ability to Maintain Level Flight, Single Engine" Chart.

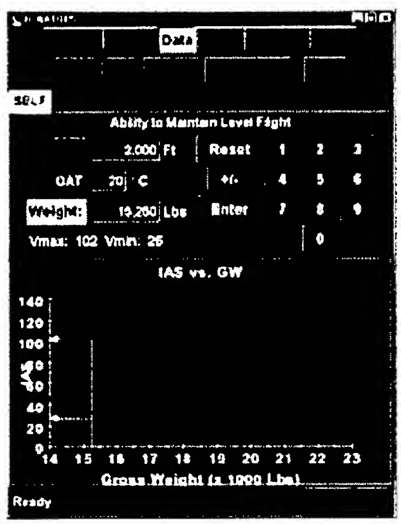

Figure 9. Performance Data Calculations Screen

The "Ability to Maintain Level Flight, Single Engine" performance chart provides the aircrew with the minimum and maximum velocities the aircraft should be flown to maintain level flight with one engine inoperable. These velocities are determined using the pressure altitude, outside ambient temperature, gross weight, and operating engine torque of the current aircraft flight profile. This information will be obtained from aircraft sensors, and the velocities can then be calculated automatically. Alternatively, the aircrew

can manually input any of the parameters to obtain the limiting velocities. For example, if the aircrew decides to fly at a higher pressure altitude, they would click on the PA field to clear and enter the new altitude via the keyboard. The velocities will be calculated automatically. The chart on the bottom of Figure 9 represents the Vmin and Vmax values over a range of gross weights. The arrows indicate the Vmin and Vmax for the gross weight shown on the screen. This chart can also be configured to show Vmin and Vmax across a range of pressure altitudes. The respective charts can be displayed by simply selecting the "Chart" button next to the PA or Gross weight text boxes. A set of tools are also being developed to aid pilots in their interactions with performance charts. These tools will be described in a later section of this report.

1.2.2 IE-NATOPS Prototype

Based on an iterative process that involved input from subject matter experts as well as end-users, the initial design was modified slightly. Perhaps the largest difference between the IE-NATOPS prototype and the initial design is in terms of how the main menu is set up for the NATOPS portion of IE-NATOPS. Specifically, in an effort to keep the prototype IE-NATOPS consistent with the look of the current NATOPS it was decided to keep the NATOPS "main menu" in the form of a table of contents (similar to how the hard copy NATOPS is currently designed). Thus, the NATOPS main menu changed from that illustrated in Figure 4 to that illustrated in Figure 10 below.

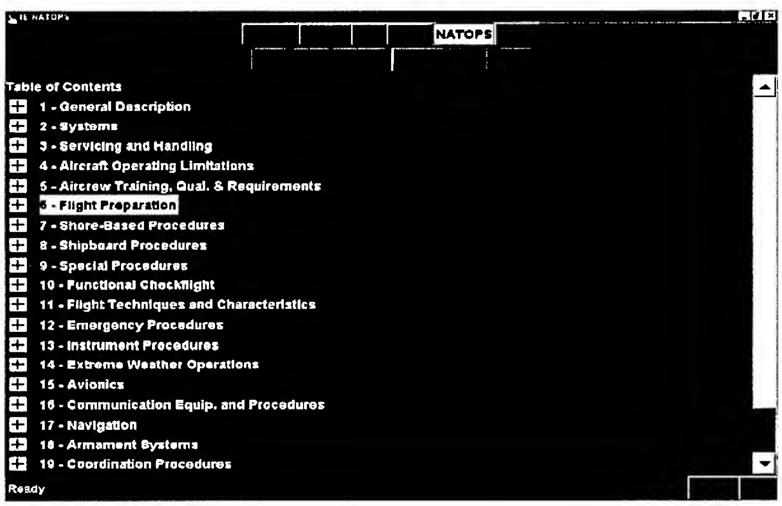

Figure 10. Prototype NATOPS main menu

Another benefit to the current configuration of the main menu is that it reduces the amount of button pushing required in order to get to needed information. In the initial design, information of this nature would have been found two levels down. Information here is organized in a tree fashion in which participants wishing to obtain more information simply expand the major chapter headings by clicking on the "+" symbol on the left. For example, expanding the "Systems" chapter reveals the subordinate subtopics

(see Figure 11). Those sub-topics with "-" to the left of the topic indicate that they are fully expanded, while those with a "+" can be further expanded.

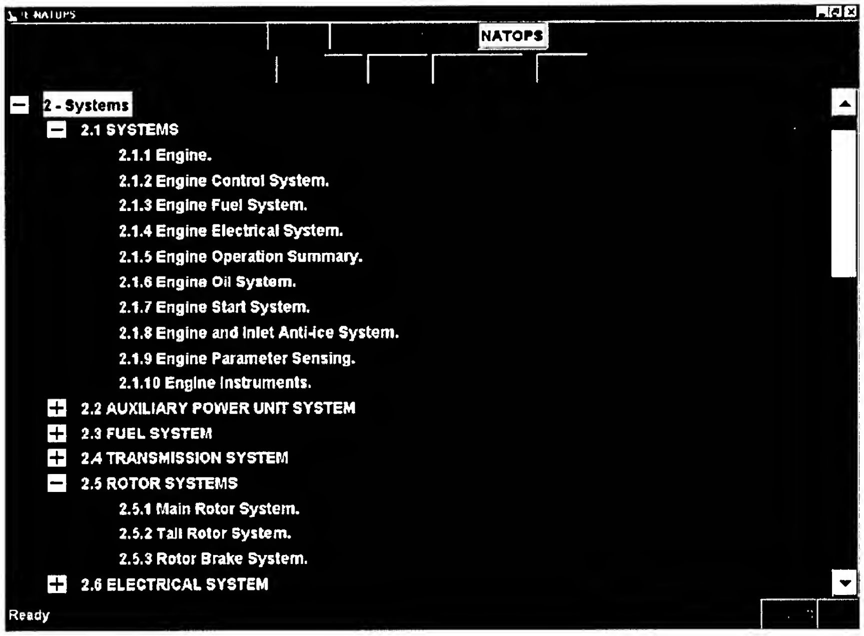

Figure 11. Prototype Systems Menu Tree.

Once the user fully expands a specific subsection, information is illustrated as it was with the initial design (see Figure 12 and Figure 7). Furthermore, as with the initial design, the user can also follow a similar path through the checklist mode hierarchy menus to access individual checklist procedures (see Figure 8). Performance data calculation screens are also similar to that of the initial design (see Figure 9) within this later prototype.

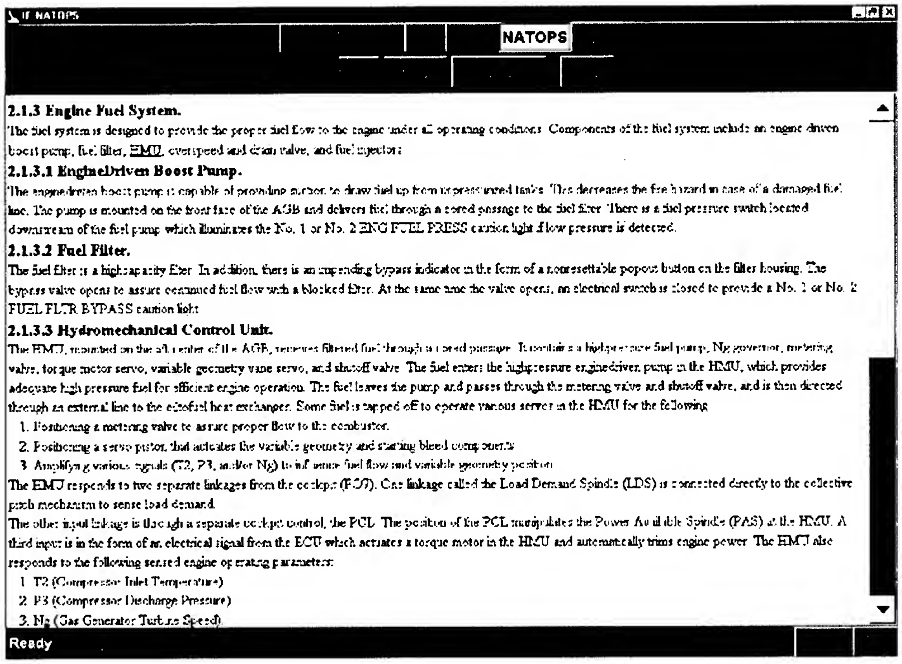

Figure 12. Prototype NATOPS Text Screen

1.3 IE-NATOPS Benchmark Evaluation

A benchmark evaluation of the IE-NATOPS design was conducted in the H-60 rotorcraft. As part of that evaluation, a detailed knowledge engineering effort was conducted in the last quarter of 2000 with pilots at VX-1 (NAWCAD) to identify current usage of the NATOPS and Pocket Checklist (PCL) while airborne (Deaton, Burke, & Good, 2000). Questionnaire and interview protocols were developed and data were obtained to identify and prioritize specific tasks accomplished with the use of the NATOPS and PCL. This effort also addressed information requirements associated specifically with graphics usage. Results from the knowledge engineering study were used to define the criterion tasks for the design of the benchmark evaluation discussed in this report. Major participating organizations in this effort have included CHI Systems, Inc., Honeywell Laboratories, Pennsylvania State University Applied Research Laboratory, the University of Central Florida, the Naval Air Warfare Center Training Systems Division (NAWCTSD), and the Office of Naval Research (ONR).

The purpose of the benchmark evaluation was to compare aircrew performance when using the traditional paper copy of NATOPS and the Pocket Checklist (PCL) with that of the prototype IE-NATOPS. Prior research addressing the integration and interpretation of text information presented either on paper or in electronic form has found significant differences favoring paper-based presentation of text in terms of search times and comprehension (Rice, 1994; Gould et al., 1987; Askwall, 1985). Though search times seemed to be shorter with paper-based text presentation compared to electronic presentation, readers have been found to search almost twice as much information when using paper-based presentation of text than when using electronic presentation (Askwall,

1985). Possibly related to these findings, Rice (1994) has found that reading comprehension is maximized when paper-based presentation of text is used compared to electronic presentation.

Both the Askwall and Rice studies used short stories as the source of their stimuli in laboratory settings, with university students as participants. When an electronic checklist was used as the source of information in training flight simulations with aviators, fewer subsystem failures were detected by the aviators than when a paper checklist was used (Palmer & Degani, 1991). When the checklist was automated, with the automated checklist checking aircraft systems and automatically highlighting missed steps, the aviators' detection of subsystem failures was even less likely than for the manually sensed electronic checklist. Related to these findings, Mosier et al. (1992) found that trouble-shooting was less accurate when electronic formats of the checklist were employed than when the paper format was employed. In addition, aircrews communicated less about the status of the aircraft when using the electronic checklist formats than the paper formats. Finally, recent work conducted by Boorman (2000) has shown that the B777 electronic checklist design developed by Boeing has reduced flight crew errors. However, the author pointed out that it could have produced new error modes were it not for explicit efforts to avoid such problems.

The results of studies performed to date reveal mixed results when using electronic formats for the aircraft checklist. In an attempt to clarify this issue and to establish the problem-solving performance of aviators using IE-NATOPS, a benchmark evaluation was performed. As with past studies, this benchmark evaluation attempted to establish whether or not there are notable differences in resolving problem situations dependent upon the format (electronic vs. paper) of the NATOPS and PCL used. Within the context of the benchmark evaluation two studies were conducted: (a) one involving experimenter-directed searches for information and so providing a measure of pure physical access time to navigate through the relevant interface to reach the desired informations, and (b) one involving self-directed searches for information needed to resolve a problem as a measure of search times that incorporate the variations due to search strategies. The results of this evaluation will be used to guide further development of IE-NATOPS.

1.4 NATOPS Graphic Evaluation

As paper manuals are converted into electronic display systems, the issue of how to display large figures and schematics on small displays is of considerable concern. Modern advances in the design of information systems have resulted in more capable, lightweight, low-power, high-resolution, portable information devices. The availability of powerful and cost-effective technology has fueled the trend towards putting more and more information into electronic form. The trend of converting paper materials into electronic form, however, may not always be a complete solution (Frey, Rouse, & Garris, 1992). A piece of paper has hundreds of times the resolution of an electronic display, so figures and pictures often cannot be shown at their full resolution all at once. The trend towards smaller display screens on portable devices only exacerbates the problems of

resolution and available screen real estate on which to display graphic figures and schematics. When this situation arises, the question then becomes 1) how best to initially display the image, and 2) how to allow the user to manipulate and interact with the image. Some of the logical solutions for interacting with an image might be to provide the functionality of zooming, panning, or scrolling which would provide the user with a small "window" through which to view the image. Scrolling and panning allow the user to maintain the field of view, but changes the portion (or "window into") of the figure being viewed. Zooming decreases the field of view, but maintains the portion of the display that is being viewed. In addition, methods of branching (i.e., hyperlinks) allow users to change the field of view, but can involve changing the representation of the entire system. Each of these techniques would provide additional representations to the user that might allow them to interact with the image more effectively. However, these solutions have limitations. For example, changing locations in an image with any of these techniques might become tedious or, more importantly, might cause the user to lose his/her focus of the "big picture" that the image represents.

The problem of usability of graphics information in IE-NATOPS has been of particular concern throughout the development of this concept. As the NATOPS manual content is digitized and moved onto electronic displays, the question arises of how to most effectively view large pictures. Electronic screen real estate is limited, so it becomes impractical to display large pictures on small screens. One possibility for continuing to provide all the information in the original graphic is simply to scale the image such that it could be accommodated by the display device. However, simply scaling down the image can potentially render it unreadable. This problem will likely be exacerbated in the context of the electronic kneeboard that is currently planned as the IE-NATOPS' host, since this device offers screen size options only in the range of 6-inch to 8.5-inch (diagonal). Furthermore, cockpit vibration may significantly exacerbate this situation. Accordingly, we have developed a variety of concepts for an IE-NATOPS Graphics Interaction Tool (GIT) that will enable the user to have access to graphic information needs in a way that permits adaptive software to reconfigure the relevant graphic information and achieve effective presentation within the display constraints.

In addition to the benchmark evaluation description, this report will identify the problems associated with displaying and interacting with graphical images that are presented in paper NATOPS manuals. Also provided is a description of a set of graphical interaction tools that have been conceptualized to enhance the usefulness of information provided to the pilots in various types of charts found within NATOPS

1.5 Organization of Report

The body of this report presents the methods used in the benchmark evaluation and the results and discussion of all facets of the study. Appendices in the back of this report contain the paperwork used to brief, debrief, and acquire biographical information about the participants. Appendices also include additional details on several of the analyses reported in the main body of the report. The IE-NATOPS training protocol is also

provided in the appendices, as are the evaluation scenarios, a preliminary task analysis of the scenarios, subject notes, and the post-evaluation questionnaire.

2. Methods

2.1 Apparatus

This benchmark evaluation employed a paper-based simulation of the information search and decision processes involved in performing missions requiring the use of the H-60F helicopter's NATOPS information in the context of scripted flight scenarios. Briefing, debriefing, biographical, and post-experiment questionnaires, training materials, and experimental scenarios were all paper-based. Both a paper version of the NATOPS Pocket Checklist (PCL) and an electronic version of the NATOPS represented by the IE-NATOPS/PCL were employed.

The IE-NATOPS system and interface were hosted on a PC computer and standard monitor. Although this study employed a desktop PC, eventually we envision that processing and display will be via a dedicated "electronic kneeboard", which consists of a pen-based, flat panel display that mounts on the pilot's thigh and is connected by wire to a chassis mounted processor with a removable storage device. The IE-NATOPS interface was scaled down to the 6in. display size of the future kneeboard device. A mouse was used to make all interactions with IE-NATOPS. It is actually expected that airborne use of IE-NATOPS would more likely be via a touch screen using a stylus, and the interface has been designed for touch-stylus operation; however, performance differences between mouse and stylus operation are expected to be negligible in the context of this study because relatively few pointing actions are required and those actions will consume very little time relative to the composite performance times to be analyzed.

Participant biographical data (see Appendix D), and post-experiment questionnaire forms (see Appendix E) were developed and presented to the participants in this study. The participant biographical data form gathered information on the participants' flight experience. The post-experiment questionnaire queried the participant's opinions of the experiment, training, and NATOPS displays.

Training materials were developed and can be examined in Appendix G. The procedure section (Section 2.5) will describe the specific training protocol used to train participants on the IE-NATOPS display.

2.2 Participants

Ten fleet replacement pilots stationed at Naval Air Station Jacksonville participated for a period of 2.5 to 3 hours each. All Naval aviators participating in this study had current experience in the H-60F. Table 1 summarizes pilot background/flight experience as well as numerous other demographic variables.

Table 1. Biographical Information and Related Flight Experience

Demographic Information/ Flight Experience	Response
Rank	LT=7 LCDR=3
Sex	Male=10
Age	M=31.8 yrs
Time in Service	M=125.8 mos.
H-60F Flight Time	M=855.0 hrs
H-60F Simulator Flight Time	M=29.5 hrs
Flight Time (last 90 days)	M=188.8 hrs
Flight Time Wing	M=1782.0 hrs
Total Flight Time	M=1909.0 hrs

2.3 Experimental Design

The main question to be answered by this benchmark evaluation was whether there are notable differences in performance dependent on the search tool used (i.e., paper or electronic NATOPS). As access to aviators was limited, this study employed a within-subjects design to examine the effects using the paper-based version of the NATOPS/PCL as compared to using IE-NATOPS. In an attempt to control for possible order effects, the method of presenting the NATOPS and PCL information (i.e., paper or electronic) was counterbalanced.

Within the overarching framework of this benchmark evaluation, participants completed two experiments that built upon one another. The first experiment served two purposes: (a) train participants on the use of IE-NATOPS and (b) determine whether *access* time differed using IE-NATOPS as compared to the traditional paper NATOPS and PCL. The dependent variable, access time, was defined as the length of time it took participants to find particular information when guided by the experimenter. The second experiment examined a different aspect of participant performance by looking at the length of time it took participants to locate what they felt were the answers to specific problem scenarios that were presented. Thus, the primary dependent variable in the second experiment was defined as the total time it took participants to self-direct themselves in the search of what they felt was the path to the correct answer for each of the problems presented. Performance in the second experiment involved both the time it took participants to *search* for the information, as well as the time it took to actually *process* the information into answers to the scenario problems. Both experiments compared performance using the paper NATOPS/PCL to performance with the electronic version of the NATOPS/PCL (IE-NATOPS).

The other-directed trials (Experiment 1) and the self-directed trials (Experiment 2) required participants to do slightly different tasks. Within the other-directed trials, we were interested solely in examining the time it took for participants to access the information using alternative versions of NATOPS (paper and electronic). Accordingly, participants were told step-by-step where to go. This required only that they remember how to use the decision-aids to which they were currently exposed (paper-based or IE-

NATOPS). It was felt that this would be akin to a situation where participants knew exactly where they needed to go to find the information, reflecting pure access time. This also provided a further assessment of the effectiveness of training. Conversely, the self-directed trials reflected a combination of search strategies and access rates. Participants had to decide how to navigate through the interface (paper or electronic) to find the desired information (search strategy), as well as to execute that strategy to arrive at the appropriate end-point. Thus, the two experiments, though connected, reflected different types of aviator performance. Furthermore, all participants completed the other-directed experiment assessing pure access rates prior to the self-directed experiment that also involved navigation strategy, as the ability to access the information was fundamental to the more complex performance reflected in the second experiment.

2.4 Procedure

Participants were given: (a) an experiment briefing (Appendix A), (b) an informed consent form (Appendix C), (c) a privacy act statement (Appendix B), and (d) an anonymous demographic questionnaire (Appendix D) that covered both experiments. Upon completion of the briefing and demographic questionnaire, participants began the experimental session(s).

2.4.1 Experiment One: Other-Directed Search

The order in which participants received the two formats of the NATOPS and PCL (paper version or IE-NATOPS) was counterbalanced. The procedure that is described below is for participants who received the paper version of the NATOPS/PCL first, followed by the IE-NATOPS condition. For participants who received the IE-NATOPS condition first, followed by the paper condition, the order of the procedure was reversed. Specifically, participants were trained on the use of IE-NATOPS, completed the searches using this tool, and then completed searches using the paper version. See Figure 13 for a depiction of the flow of events, dependent upon the order of counterbalancing.

Paper NATOPS First, then IE-NATOPS

Paper NATOPS Evaluation	IE-NATOPS Training	IE-NATOPS Evaluation

IE-NATOPS First, then Paper NATOPS

IE-NATOPS Training	IE-NATOPS Evaluation	Paper NATOPS Evaluation

Figure 13. Experiment 1 Timeline

For individuals assigned to the paper-based condition, the experimental procedure was as follows. Participants were instructed by the experimenter to go to specific sections of the NATOPS/PCL, verbalizing their path along the way. The searches that participants completed required them to transverse through multiple sections of the paper-based NATOPS/PCL (see Appendix H). Two evaluators were seated in close proximity to record when participants reached their final destination, as indicated by the experimenter. No training was given on the use of the paper-based NATOPS /PCL for it was assumed that pilots were well trained on the use of this format as a result of regular NATOPS exams and daily use. Following performance on the paper-based version, participants were asked if they had any remaining questions on what they had just completed.

Participants were then told that the next section of the study would require them to use an electronic version of the NATOPS/PCL and that, prior to using the electronic version, a short training session would be conducted to enable them to operate the electronic version. Training on the use of IE-NATOPS was an interactive hands-on process that was led by the experimenter. Training proceeded in a manner such that participants learned general information about the design and structure of IE-NATOPS followed by instruction on each of the specific modes (i.e., checklist, data, alert, and NATOPS) contained in IE-NATOPS. Participants were then given ten minutes to practice a list of objectives that required them to transverse among the different modes of IE-NATOPS. At the completion of the ten minutes, participants were asked if they had any questions or concerns. Finally, the experimenter asked participants to traverse through the database to find several specific items of information. Participants were presented with progressively more complex tasks using IE-NATOPS, each of the tasks building upon previous tasks. In this way, participants received practice in the basic navigation skills required to access information in IE-NATOPS. This last practice session was akin to what participants would be required to do on subsequent experimental trials. See Appendix H for a copy of the script used during this training.

Total training time on IE-NATOPS lasted approximately thirty minutes for each participant. This duration of training was determined to be adequate through pilot trials. Participants were allowed to progress forward if they felt comfortable with the interface and the experimenter judged that they were adequately manipulating the interface so that the actual manipulation of the interface would not be a problem during the experiment.

At the completion of training, participants were told that they would begin the portion of the study that required them to locate specific information, as dictated by the experimenter, using IE-NATOPS. Participants were to follow the same procedures that were followed for the searches using the paper-based version of the NATOPS/PCL. See Appendix H for further detail on the specific searches required. Aaccess time was computed by two evaluators using stopwatches. At the conclusion of the first experiment, participants were informed that they could take a short ten-minute break and upon their return they would begin the second experiment (as described in the pre-brief and informed consent).

2.4.2 Experiment Two: Self-Directed Search

As with the first experiment, the format of the NATOPS and PCL was counterbalanced. In addition, problem scenarios were also counterbalanced. Upon return from break from their sessions for the Experiment One, each participant was again seated at a desk and presented with written problem scenarios, one at a time, totaling ten scenarios. Each participant was asked to resolve each of the ten problem scenarios using the NATOPS information for the H-60F (Appendix I). For five of the scenarios the participant was restricted to using the paper NATOPS/PCL, while the remaining five scenarios involved access to NATOPS/PCL information through the use of IE-NATOPS. The procedures used by the participants to resolve the problem scenarios were directed to be those currently used by these naval aviators in their aircraft and are explicitly stated in the H-60F NATOPS. See Appendix I for further detail.

Experimenters observed how the participants resolved the specific problems in each scenario, noting how long it took participants to reach a solution and the outcome of that solution (i.e., accuracy). Once participants had read a scenario, they were given the opportunity to ask any questions relative to the problem being presented. Participants were asked to state verbally how they would resolve the problem situation (i.e., what information they would access within NATOPS/PCL). Once that process was completed, participants were instructed to trace the path within the NATOPS/PCL that would lead them to their correct answer. Timing (via hand-held stopwatches) began once each individual verbally stated their plan for accessing the needed information and indicated that they were starting the active navigation process. The completion of the response time was defined as the time when the participant verbally stated the solution by accessing it on the screen or in the paper version of the NATOPS/PCL.

2.4.3 Debriefing

After participants completed both experiments, as well as the post-experiment questionnaire, they were debriefed as to the overall purpose of the studies (see Appendix F).

2.4.4 Graphics Evaluation

Following the debriefing, the evaluation of graphical concepts and tools proposed for use within IE-NATOPS took place. Each participant was told that they would now be shown a variety of concepts that included tools for interacting with large graphical images within NATOPS. This portion of the evaluation was set up in an interview format. The experimenter described each concept and then solicited feedback from each participant on each of the concepts. Upon completion of this portion, participants were thanked for their participation and any questions that remained were answered.

3. Results

3.1 Descriptive Information

A scan for outliers (scores more than +/- 3 standard deviations from the mean) resulted in three individuals being deleted in analyses of experimenter-directed search data and two individuals being deleted in analyses of self-directed search data.

Correlations between key study variables and demographic variables are presented in Appendix J (Table J-2). Overall, demographic variables were not correlated with key study variables, but there were two exceptions. Within Experiment 1, amount of time spent in the 60H in the last 30 days was positively correlated with access time using the paper copy of the NATOPS/PCL. Within Experiment 2, amount of time spent in the H-60F simulator was positively correlated with search time using the electronic version of the NATOPS/PCL (IE-NATOPS). Thus, it is possible that the amount of time spent in the 60H in the last 30 days and the amount of time spent in the 60F simulator might explain a portion of the variance accounted for in other-directed and self-directed search times, respectively.

3.2 Experiment 1: Other-Directed Search

To investigate the impact of search mode/format on access time, a 2 (search mode) x 6 (trials) repeated measures ANOVA was conducted. Within this analysis, amount of time spent in the H-60H in the last 30 days was used as a covariate. With the covariate entered in, results indicated a main effect for search mode ($F(1,5)=97.05$, $p<.01$, $eta^2=.951$). Specifically, when participants used the electronic search mode/IE-NATOPS ($M=56.55$, $SE=2.01$), access times were significantly quicker than when the paper search mode (hard copy NATOPS/PCL) was used ($M=106.26$, $SE=4.07$). See Figure 14.

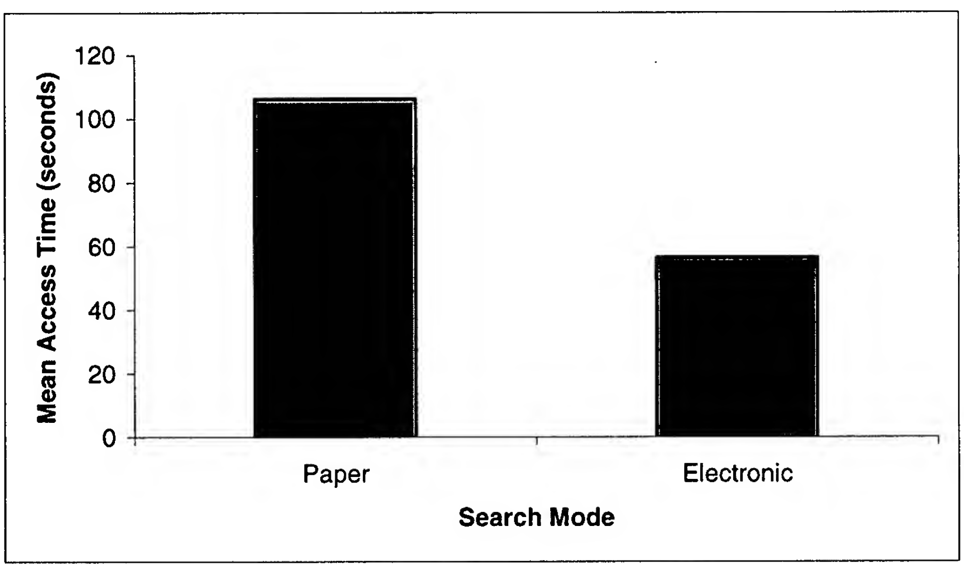

Figure 14. Mean Access Time by Search Mode

Results also indicated a main effect for content-access trial ($F(1.481, 7.404)=16.80$, $p<.01$, $eta^2=.771$), indicating that participants had significantly different access times dependent on the particular content-access trial (the Mauchly's Test of Sphericity was significant, thus the Greenhouse-Geisser correction was used). See Figure 15 for a pictorial view of this result.

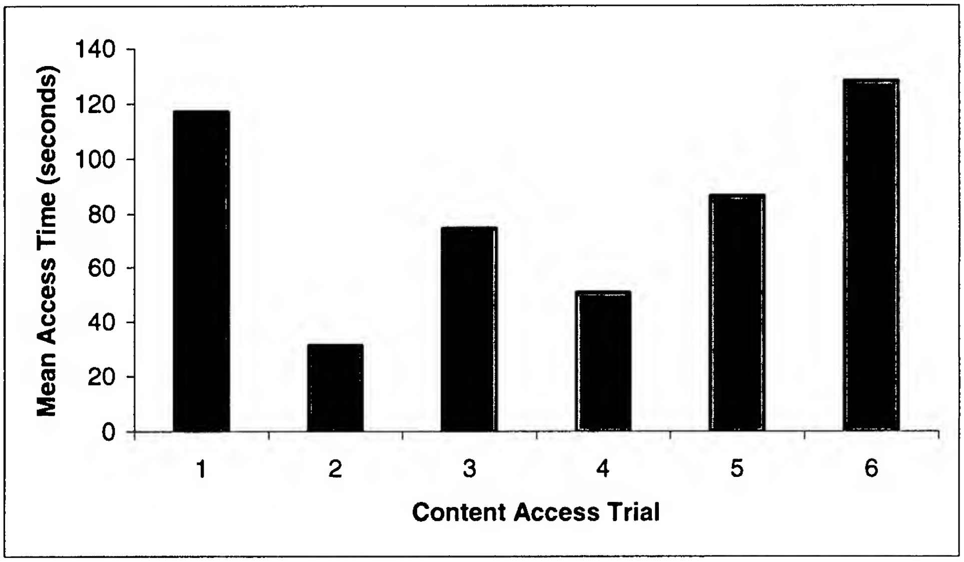

Figure 15. Mean Access Time by Content-Access Trial

The intention of this portion of the study was to design content-access trials to cover a range of actions and to ensure that participants were capable to operate the electronic search tool (IE-NATOPS). It was not to examine individual trials. Hence, a priori hypotheses were not formulated regarding the effect of individual trials. However, given the significant main effect, post-hoc comparisons were conducted using a modified Bonferroni correction (as suggested by Kinnear & Gray, 1997). Due to the corrections made, a more conservative p value must be used (as compared to the normal p of .05 or .01). Specifically, in order for a comparison to be deemed significantly different, the p value must be less than .003. Given this, the following trials were found to represent significant differences: (1) Trial 2 vs. Trial 3, (2) Trial 2 vs. Trial 5, and (3) Trial 2 vs. Trial 6. The differences between access times during Trial 2, as compared with most other trials, makes intuitive sense in that the information that participants were directed to access in Trial 2 represented a short two-step procedure, whereas the other trials were more complex (i.e., required more steps). Although the graphical depiction above is deceiving, in that it looks like the difference between Trial 2 and Trial 1 would also be significant, access times during Trial 1 experienced a great deal of variation. Specifically, the access times in Trial 1 had a standard error of 15.60, and a 95% confidence interval of 76.98 to 157.17. The reported standard error of all other trials ranged from a minimum of 2.6 (Trial 2) to a maximum of 8.78 (Trial 6).

Finally, a non-significant interaction ($F(2.119, 10.597)=2.88$, $p>.05$, $eta^2=.365$) was found indicating that search mode and content-access trials do not interact to produce different participant access times (Greenhouse-Geisser correction used).

3.3 Experiment 2: Self-Directed Search

Experiment 2 was conducted to examine whether search mode (paper or electronic) had an effect on participant self-directed search time. The design of the second experiment was set up slightly differently than the first experiment, precluding a factorial ANOVA, as used in experiment 1.

3.3.1 Primary Analyses

Results of a repeated measures ANOVA, using time spent in the H-60F simulator as a covariate, indicated that search mode did not significantly impact search time ($F(1,)=3.46$, $p>.05$, $eta^2=.409$). Indicating that, on average, search mode did not affect the time it took for participants to search for the required information and then once found, process that information (paper M=184.23, SE=20.06; electronic M=164.51; SE=18.16). While not significant, results did show a more rapid response for participants using the electronic mode.

Because participant's searches were self-directed, a second set of analyses were conducted to examine whether search mode had an effect on the accuracy of participant responses to each problem scenario, as judged by a subject matter expert (SME). Examination of summary statistics clearly shows that there was very little variance in accuracy rates. In fact, for both search modes, participants tended to answer correctly 94% of the time. See Table 2 for more detail. Appendix J provides additional detail on specific subject accuracy performance by scenario.

Table 2. Accuracy of Response (Summary Statistics)

	Mean	Standard Deviation	Minimum	Maximum	N
Scenario 1					
Paper	1.00	.000	1.00	1.00	4
Electronic	.75	.500	0.00	1.00	4
Scenario 2					
Paper	1.00	.000	1.00	1.00	2
Electronic	1.00	.000	1.00	1.00	6
Scenario 3					
Paper	1.00	.000	1.00	1.00	4
Electronic	1.00	.000	1.00	1.00	4
Scenario 4					
Paper	1.00	.000	1.00	1.00	2
Electronic	.83	.408	0.00	1.00	6
Scenario 5					
Paper	1.00	.000	1.00	1.00	4
Electronic	1.00	.000	1.00	1.00	4

Scenario 6					
Paper	1.00	.000	1.00	1.00	4
Electronic	1.00	.000	1.00	1.00	4
Scenario 7					
Paper	.83	.408	0.00	1.00	6
Electronic	1.00	.000	1.00	1.00	2
Scenario 8					
Paper	1.00	.000	1.00	1.00	4
Electronic	1.00	.000	1.00	1.00	4
Scenario 9					
Paper	.67	.516	.000	1.00	6
Electronic	.75	.500	.000	1.00	2
Scenario 10					
Paper	1.00	.000	1.00	1.00	4
Electronic	1.00	.000	1.00	1.00	4

3.3.2 Ancillary Analyses

Within the second experiment, each participant completed 10 scenarios that were counterbalanced across search mode. For each participant, five of these scenarios were completed via a paper search and five via an electronic search. The study was designed in this manner due to the fact that the intent was not to examine individual scenarios, but how search mode affected search times across scenarios (accordingly, SMEs had designed and assessed the scenarios to exhibit similar complexity). However, observations during the study suggested that there may have been a slight interaction between search mode and individual scenarios. Because of design constraints, the authors felt that statistical analyses were not appropriate in this instance. However, an examination of descriptive information, broken down by search mode, may provide insight into trends and areas of future research. Table 3 presents these data in tabular form and it is illustrated graphically in Figure 16. The figure presents these data in terms of error bars extending one standard error above and below the mean in each case.

Table 3. Search Time for Problem Solving Trials: Trial x Search Mode

	Paper	Electronic
Scenario1	M=178;SE=27	M=77;SE=23
Scenario2	M=170;SE=217	M=84;SE=42
Scenario3	M=131;SE=14	M=34;SE=12
Scenario4	M=200;SE=113	M=265;SE=70
Scenario5	M=274;SE=92	M=214; SE=108
Scenario6	M=103;SE=26	M=104; SE=30
Scenario7	M=224;SE=47	M=458; SE=242
Scenario8	M=187;SE=30	M=219; SE=36
Scenario9	M=174;SE=40	M=196;SE=64
Scenario10	M=202;SE=86	M=221;SE=73

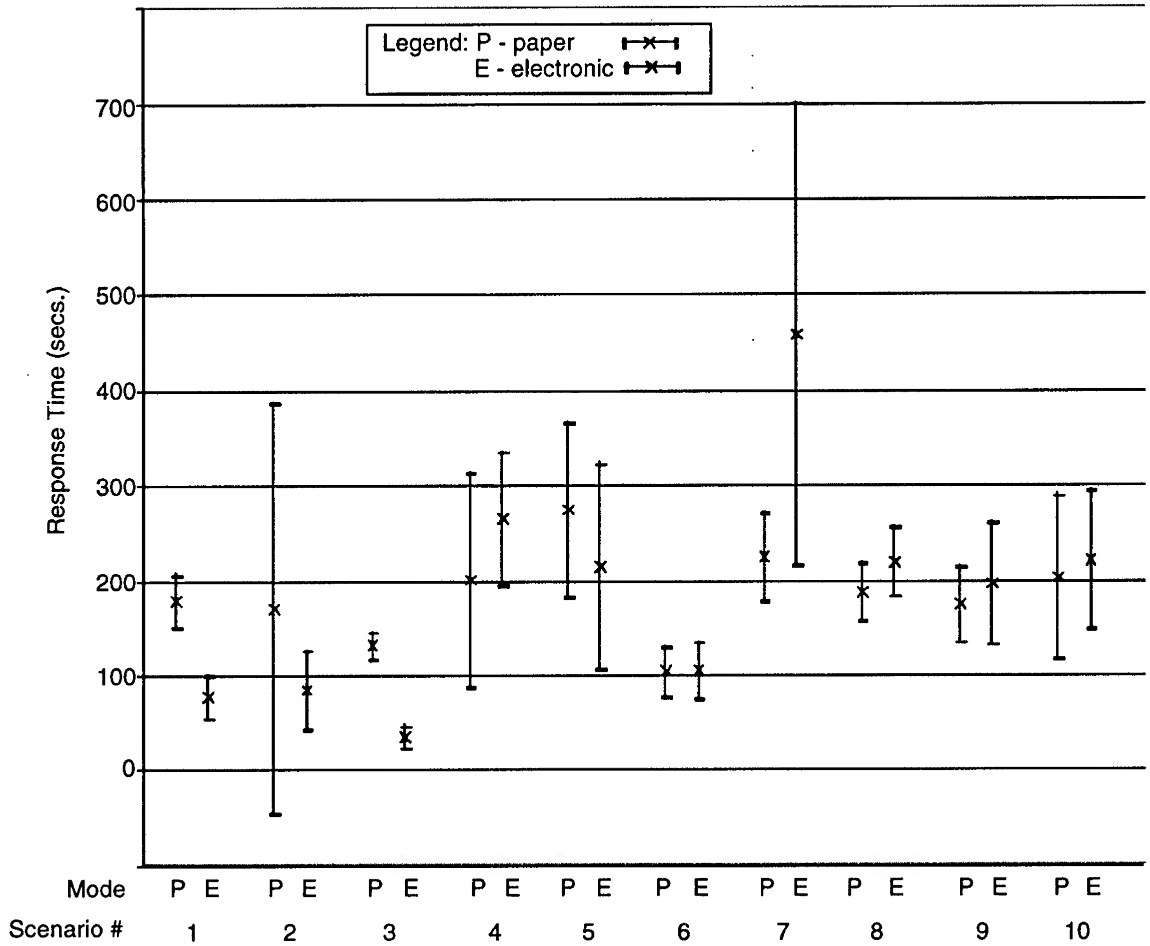

Figure 16. Search Time for Problem Solving Trials: Error Bars

In examining the descriptive information presented above, perhaps the first thing that the reader needs to remember is that, as the above means and standard errors represent participant search times, smaller numbers indicate more rapid response times. In addition, there are a few trends that might provide some additional insight into current findings. In terms of the scenarios themselves, the data indicate that some scenarios witnessed extremely large standard deviations (see scenarios 2, 4, 5, and 7). The large variability in participant responses within these scenarios makes it difficult to determine the effect of search mode. Secondly, although scenarios were not designed to target specific characteristics, but to cover a range of problems that pilots might face, a cursory analysis can be made as to how scenario content may contribute to the above patterns. At a general level, the following observations can be made. The scenarios in which participants had quicker search times via the electronic search mode generally had the following characteristics: (1) required use of a performance chart or (2) involved a checklist that required participants to go to another section/checklist (hyperlink provided). Moreover, the scenarios in which participants' search times were quicker using the paper search mode tended to be searches that involved: (1) finding tables or (2) general text. Appendix L provides a preliminary task analysis of the 10 scenarios, and may shed some light on how scenario characteristics interact with presentation mode.

3.4 Post-Experiment Questionnaire

Table 4 presents the mean response rates for the post-experiment questionnaire (see Appendix E for detailed wording of each question). Questions 1-4 dealt primarily with the IE-NATOPS training that was afforded each participant during the first experiment. Questions 5 and 11-12 were associated specifically with aspects of the IE-NATOPS interface. Questions 6-10 compared paper NATOPS and IE-NATOPS on numerous dimensions. Note that different scales and scale ranges were used for these questions, in particular with Questions 1-5 using three-point scales and Questions 6-12 using five-point scales; all reported comparisons are within a single scale type.

Responses on Questions 1-4 indicated that participants, in general, agreed that IE-NATOPS training was well organized, thorough, well-paced, and included sufficiently complex practice problems to afford participants an adequate training opportunity. Responses on Question 5 showed that participants felt confident regarding their use of IE-NATOPS for acquiring information in flight. Questions 11-12 provided a measure of ease of use of numerous functions of the IE-NATOPS interface. In general, all participants agreed (or strongly agreed, in some cases) that all specified interface functions were easy to use. Those functions that were rated as the easiest to use were the tab (i.e., "file tabs" allowing selection from multiple simultaneously active checklists) feature within the checklist section and the performance charts. Those functions that were not quite as easy to use included the history function and the bookmark function.

Questions 6-10 consisted of a comparison between NATOPS and IE-NATOPS, and, thus, provided the opportunity to conduct a more quantitative/statistical comparison between participants' responses. Accordingly, five related-measures t-tests were conducted on these five matched questions. Results of this analysis indicated that the only comparison that was significant was that between 6a and 6b. In this case, participants were significantly more likely to agree with the statement that the IE-NATOPS interface, in comparison to the traditional paper NATOPS, was easier to manipulate, [$t(9) = 2.25$, $p = .05$]. The only other comparison that approached significance was that between 10a and 10b, [$t(9) = 2.09$, $p = .06$]. That is, participants rated IE-NATOPS as easier when accessing information involving searching in multiple sections. While this difference was not statistically significant ($M = 2.2$ for NATOPS vs. $M = 1.5$ for IE-NATOPS), it was in the anticipated direction. Given the nature of electronic media and their efficient searching capabilities, the research team had expected IE-NATOPS to facilitate access to information contained in physically separated sections of the traditional NATOPS. All other comparisons between NATOPS and IE-NATOPS were insignificant. However, with the exception of one question, all survey questions favored IE-NATOPS in comparison to NATOPS in terms of ease of use. The one exception was between 8a and 8b. Although not statistically significant, the means indicated that participants were less likely to agree with the statement that they had no trouble reading and understanding the NATOPS data when using the IE-NATOPS interface.

Additional analyses were performed to address potential differences on the survey questions as a function of specific grouping variables obtained from the demographic data. Accordingly, data from the survey questions were re-analyzed using the following category variables:

1) rank—LT vs. LCDR,
2) age—less than or equal to 30 years. vs. greater than 30 years.,
3) time in service—less than or equal to 105 months vs greater than 105 months,
4) total hours in the H-60F—less than or equal to 600 hours vs. greater than 600 hours,
5) approximate time in the H-60F in the last 90 days—less than or equal to 15 hours vs. greater than 15 hours,
6) approximate time in the H-60F simulator—less than or equal to 100 hours vs. greater than 100 hours,
7) total time in rotary wing—less than or equal to 1500 hours vs. greater than 1500 hours, and
8) total flight time—less than or equal to 1600 hours vs. greater than 1600 hours.

Note that with the exception of rank (there was little variability here — participants were either LT or LCDR), the criteria for determining the two groupings for each category was based on median values for each category. That is, in most cases, 50% of the participants were in each grouping (e.g., for the age category, half of the participants were less than 30 years, while the other half were greater than 30 years). Traditional t-tests for independent groups were conducted on each of these categories for the particular groups that were developed. Detailed results for these ancillary analyses are presented in Appendix K.

The additional analyses involved comparisons for all 23 of the items and sub-items of the questionnaire and across all eight grouping variables enumerated above. Thus, a total of 184 individual comparisons were made at this stage. However, since the eight groupings are highly redundant and overlapping with one another (i.e., individuals with higher rank tend to be older, with more time in service, more flight hours, etc.), these do not represent independent comparisons. Out of all of these comparisons, only three were found to be statistically significant. These are:

- Item 8a [$t(8) = 2.45$, $p = .04$] indicates that the pilots with more H-60F flight time agreed more strongly with the statement that they had no trouble in reading and understanding the NATOPS data using traditional NATOPS as a source.
- Item 11b [$t(8) = 2.89$, $p = .02$] indicates that pilots with more experience were not as likely to agree that the bookmark function was easy to use.
- Item 12a [$t(8) = 2.97$, $p = .02$] supports 11b in indicating that more experienced H-60F pilots did not find the bookmark function as useful as less experienced H-60F pilots in the operational environment.

Additionally, non-significant trends for the grouping factors of rank, age, and time in service suggested that more senior pilots (in rank, age, or time in service) rate IE-NATOPS higher for ease of interface manipulation than the more junior officers.

However, also non-significantly, more junior pilots tended to report less trouble reading and understanding IE-NATOPS.

Table 4. Overall Mean Response Rates for Post-Experiment Questionnaire

Item	Scoring Scale	Mean	SD
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.10	.32
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.10	.32
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient 3 = too much	2.10	.32
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.10	.32
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.60	.52
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	2.80	1.48
6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.50	.53
7a. Always knew how to use paper NATOPS interface	1 = strongly agree 5 = strongly disagree	2.20	1.32
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	1.90	.57
8a. Had no trouble reading & understanding paper NATOPS	1 = strongly agree 5 = strongly disagree	1.30	.48
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.60	.70
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.50	1.35
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.10	.32
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.20	1.03
10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.50	.53
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.20	.79
11b. Bookmark function easy to use	1 = strongly agree 5 = strongly disagree	2.10	.74

11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.70	.67
11d. Tab Feature in Checklists easy to use	1 = strongly agree 5 = strongly disagree	1.40	.52
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	1.70	.95
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.50	.53
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful	1 = strongly agree 5 = strongly disagree	2.44	.88
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.67	.71

3.4.1 General Comments from Pilots

The following summarizes the comments made by pilots in completing the post-experiment questionnaire:

Training

- The usefulness of IE-NATOPS will be in the aircrew's ability to quickly access emergency data. Scenarios should be developed that reflect this requirement. The scenarios used in this study were too complex.
- Some scenarios asked for some data that would not be considered in an actual scenario.

Confidence in Using IE-NATOPS

- When using NATOPS (paper), one does not always have a specific location in mind when searching for a topic — one knows approximately where to find it. The IE-NATOPS makes it difficult to approximate.
- The index and table of contents are extremely helpful.
- A little more time and I would become very confident with the IE-NATOPS.

NATOPS vs. IE-NATOPS

- NATOPS is poorly organized, but still functions because of familiarity.
- The paper PCL is difficult to use, tabs usually don't open exactly to the section needed and the table of contents is not very user friendly.
- IE-PCL is a big improvement.
- Table of contents on paper NATOPS uses procedure names that are uncommon to most thought processes.
- Resolution in some areas could be improved (IE-NATOPS).
- The search and index functions are very, very effective at finding the relevant information.
- The history, bookmark, and forward/back keys are well designed.

- History was upside-down — most recent should be at the top — didn't see much need for the bookmark function.
- The web browser needs more "intelligent" search functions.
- Very good system, but should not completely replace NATOPS. Every pilot needs a printed NATOPS and PCL to highlight, study, etc. IE-NATOPS is a great backup to knowledge we should already have.
- Performance charts should not have default values in them — once numbers are placed in the fields, the calculations should occur automatically. The current setup could lead to an error in reading old input if the enter button is not pushed.
- Normal checklists scrolling into each other would be an improvement — scroll from section to section rather than going back to the menu.

3.4.2 Correlational Analysis

A correlational analysis was conducted on the questions from the survey (1-12) and the specific demographic variables provided in the biographical information questionnaire. The following correlations were found to be significant:

1) Question 10b and flight hrs. in the H-60F [$r(8) = .67$, $p = .034$]
2) Question 11d and flight hrs. in the H-60F [$r(8) = .69$, $p = .028$]
3) Question 12a and age [$r(7) = .70$, $p = .038$]
4) Question 1 and total flight time [$r(8) = .64$, $p = .045$]
5) Question 2 and total flight time [$r(8) = .64$, $p = .045$]
6) Question 3 and total flight time [$r(8) = .64$, $p = .045$]
7) Question 9b and time in H-60F simulator [$r(8) = .96$, $p = .000$]
8) Question 1 and age [$r(8) = .65$, $p = .042$]
9) Question 2 and age [$r(8) = .65$, $p = .042$]
10) Question 3 and age [$r(8) = .65$, $p = .042$]

In summary, the above results can be loosely interpreted as meaning:

- Pilots with more experience with the H-60F were less likely to rate IE-NATOPS capabilities/functions as positive as compared to pilots with less experience (1,2).
- Older pilots with more overall flight time and/or simulator time were more likely to rate the IE-NATOPS training/scenarios as too complex, too regimented, and/or requiring too much practice time (4-6, 7, and 8-10).

3.5 Graphics Evaluation

3.5.1 Technical Approach

The approach taken in this effort started with developing an understanding of the tasks that pilots perform when using particular NATOPS graphics and schematics, studying how these graphics elements are used to support the tasks, and understanding how the

operational environment affects their use. Thus the initial step in the program was a series of interviews with pilots. This initial knowledge elicitation effort (see Deaton, Burke, & Good, 2000) was a significant driver in the conceptual design of early paper prototypes. These paper prototypes were presented to pilots in the current evaluation. This use of iterative design, where emphasis is placed on user feedback at multiple stages of design, supports the design of tools that will help pilots in the performance of tasks that require interaction with graphical figures and schematics in IE-NATOPS.

3.5.2 Graphical Interaction Tool Interviews

We conducted a series of interviews with pilots that participated in the IE-NATOPS benchmark evaluation described in this report. The purpose of these interviews was to get initial feedback on the graphical interaction tool concepts that we have developed (at Honeywell) in the course of this project. Each pilot was shown a variety of paper prototypes that described the concepts that we had developed to date. Each prototype was scaled down to mimic the size of the targeted display surface (approximately 6.4-inch diagonal screen). This was done to provide each pilot with a feeling for the size of the graphical images with which they would be dealing during flight. The interviewer described the functionality of each concept and feedback on the features of the concepts was solicited. The pilot was prompted to select the set of concepts that he felt would be the easiest with which to interact and that would provide the most utility during flight to accomplish the desired outcome.

3.5.3 Graphical Interaction Tool Concepts

This section describes the concepts that were presented to each pilot. Prior to this set of interviews, a detailed knowledge elicitation effort was conducted. For that effort, we interviewed several pilots at VX-1 (NAWCAD) to identify current airborne usage of NATOPS. Questionnaire and interview protocols were developed and data were obtained to identify and prioritize specific tasks accomplished with NATOPS. The effort also addressed information requirements associated specifically with the use of charts and other graphics within NATOPS. The results of this task suggest that performance charts and wind envelope charts are the most heavily used NATOPS graphics during flight. Therefore, the concepts we developed have focused on these two types of charts.

3.5.3.1 Performance Charts. Figure 17 represents a potential shell for displaying performance charts. Note that this figure shows a performance chart at approximately the size it would appear on the targeted display surface for this program. We felt that it was important to provide an indication to the pilots of the size and resolution that would result from simply scaling a performance chart down to meet the display size requirements. The size of the image was quite small and extracting fine detail and specific point values out of the image would be difficult. It should be noted that the display surface of the system will be touch sensitive and the pilot will be interacting with information via a pen-like stylus.

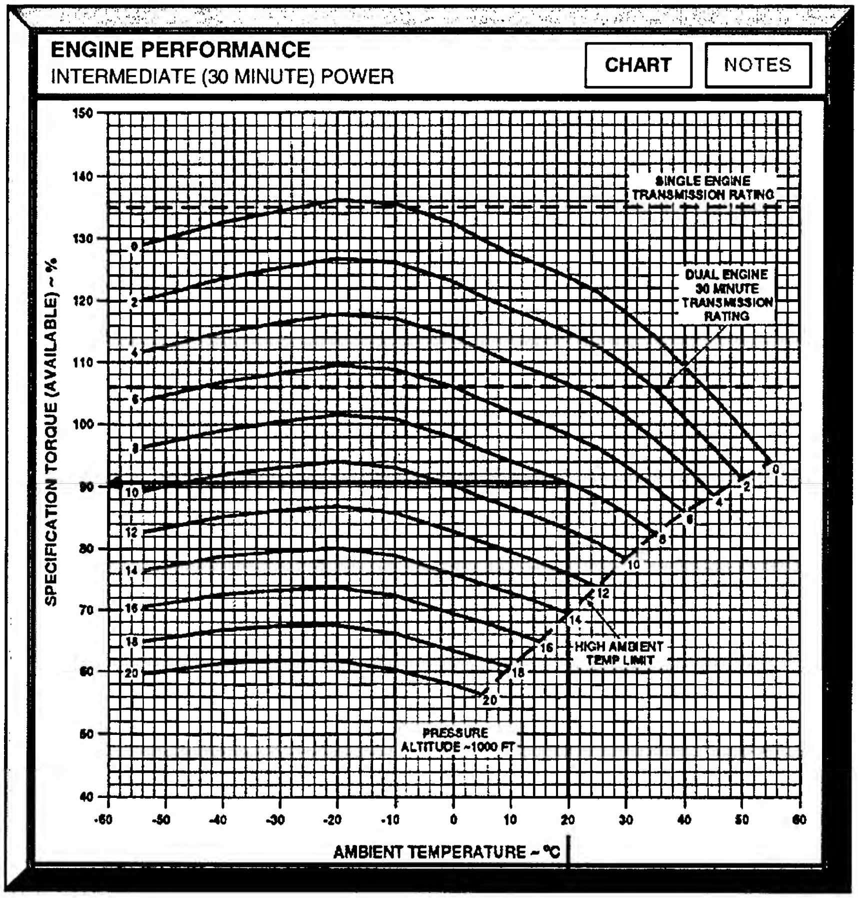

Figure 17. Example of Scaled-down Performance Chart

<u>Concept PC1</u>

At the top of the display the title of the particular chart is displayed along with other information specific to the chart. To the right of the chart title are two buttons labeled "CHART" and "NOTES". When the CHART button is selected, the performance chart would be displayed. When the NOTES button is selected, a subsequent screen would be displayed that would contain other information specific to the chart. An example of a NOTES screen is presented in Figure 18. The information contained on the NOTES page is all the information found on the NATOPS version of the performance chart. To return to the performance chart view, the pilot simply selects CHART.

<u>Concept PC2</u>

It became apparent, after viewing a performance chart at the size of the targeted display, was that it might be useful to use some sort of highlighting or magnification to emphasize particular portions of the information contained in the chart. Our first set of concepts provides a "magnifying glass" or fisheye lens that appears when the pilot places the stylus on the display surface. Our first example of this technique is presented in Figure 19.

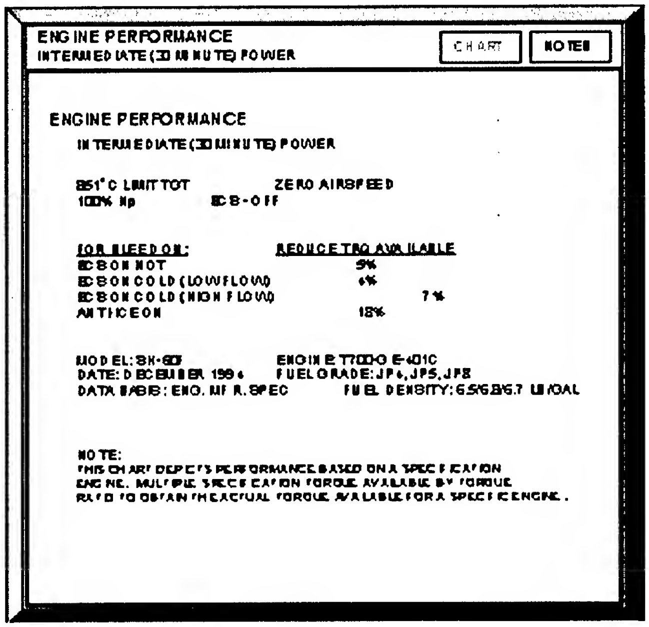

Figure 18. The NOTES Page

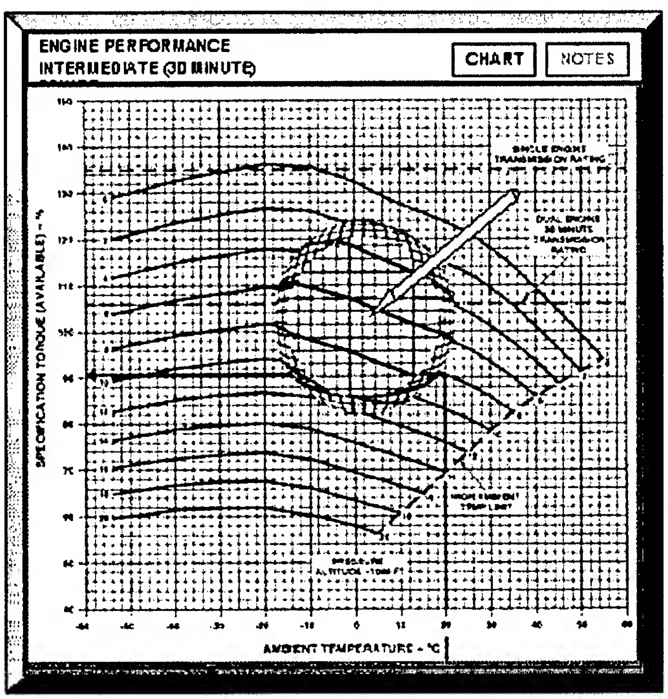

Figure 19. Magnifying Glass Concept

In this concept, touching the stylus to the display surface causes a lens appears under the stylus location. This lens has the effect of magnifying the information below the tip of the stylus. One way to think about this is to imagine a glass ball that has been cut in half.

By placing the flat side of the resulting hemisphere down on a performance chart, you create a crude magnifying glass. In addition to the magnification at the center of the lens (the "sweetspot"), the edges of the lens distort the image such that any particular line on the graph is connected on either side of the lens boundary. Thus, the user can maintain the distinction of which line is which since any particular line is still continuous across the lens boundary. The pilot is then able to move the stylus to any location on the chart and the lens will dynamically "follow" the stylus to highlight information at any location on the chart. Note that this particular performance chart does not necessarily lend itself to a magnification technique since the parameter curves within the chart are easily discernable. However, in situations where either the parameter curves converge or where many curves cross at the same point, it might be helpful to magnify those areas to provide a better understanding of what the parameter is doing in relation to the other variables displayed in the chart. Furthermore, since we are only at the concept development stage and are not certain that this concept will be useful to pilots, we have not resolved a number of factors that are relevant to this magnification concept. Factors such as the degree of magnification, the diameter of the "lens", and the diameter of the "sweetspot" that would be most useful, as well as a host of other more general usability issues (e.g., highlighting color, ease of use, etc.) would need to be resolved if this concept is pursued in a development phase.

Concept PC3

While the concept of magnifying small portions of the chart may be useful in some situations, we considered other types of information on the charts that has utility for the pilots. The way a pilot typically uses a performance chart, which is generally represented as a type of nomogram, is to trace a line from either the x or y axis to a particular parameter curve and then down to the other axis to get the value for the variable in which they are interested (complex nomograms may require repetition of this process over multiple integrated axes). Based on this interaction, we extended the earlier concept to add axis guides and dynamic labeling of axis values. This concept is presented in Figure 20.

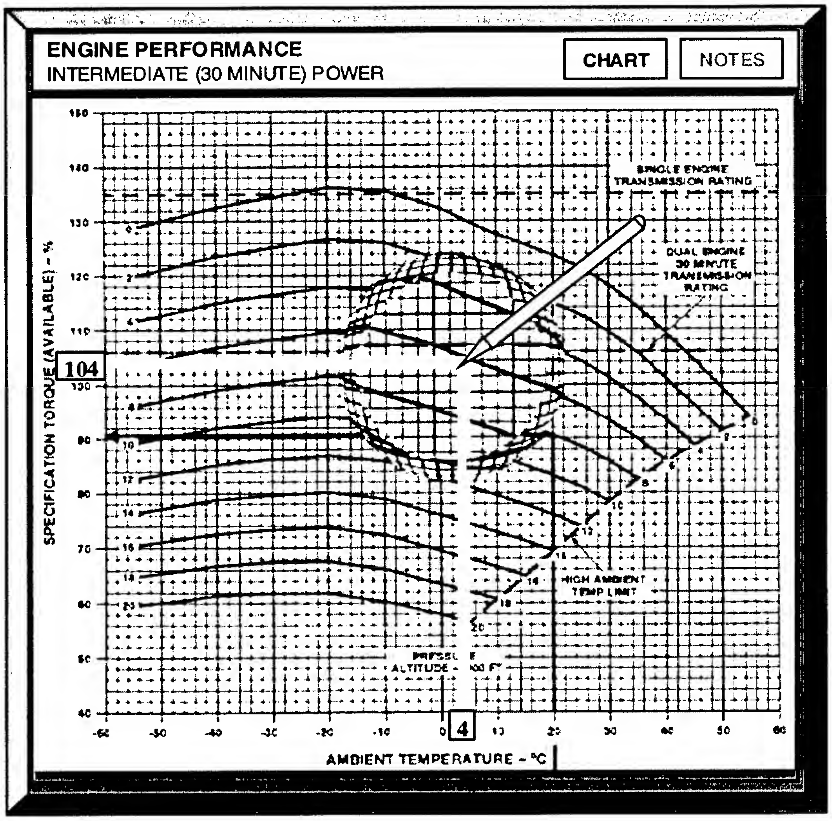

Figure 20. Axis Line/Magnifying Glass Concept

As can be seen, this particular concept provides the magnified information, but also includes horizontal and vertical lines that extend to the axis. The axis lines and axis labels are dynamic and "follow" the location of the stylus. This particular concept allows the pilot to see fine details via the magnification lens if necessary, as well as the potentially more relevant axis information immediately.

Concept PC4

We noticed during the development of the previous concept was that it quickly became visually overwhelming for the user. In addition, most performance charts do not necessarily lend themselves to the need to access very detailed parameter information through a magnifying glass. That is, in most performance charts, the parameter curves within the chart are distinct and distinguishable. As can be seen in Figure 21, this concept provides a simpler view of performance chart parameters. Essentially, the only difference between this concept and the previous one is that the ability to obtain detailed, magnified information was eliminated. The functionality of the lines extending to each axis remains the same as before.

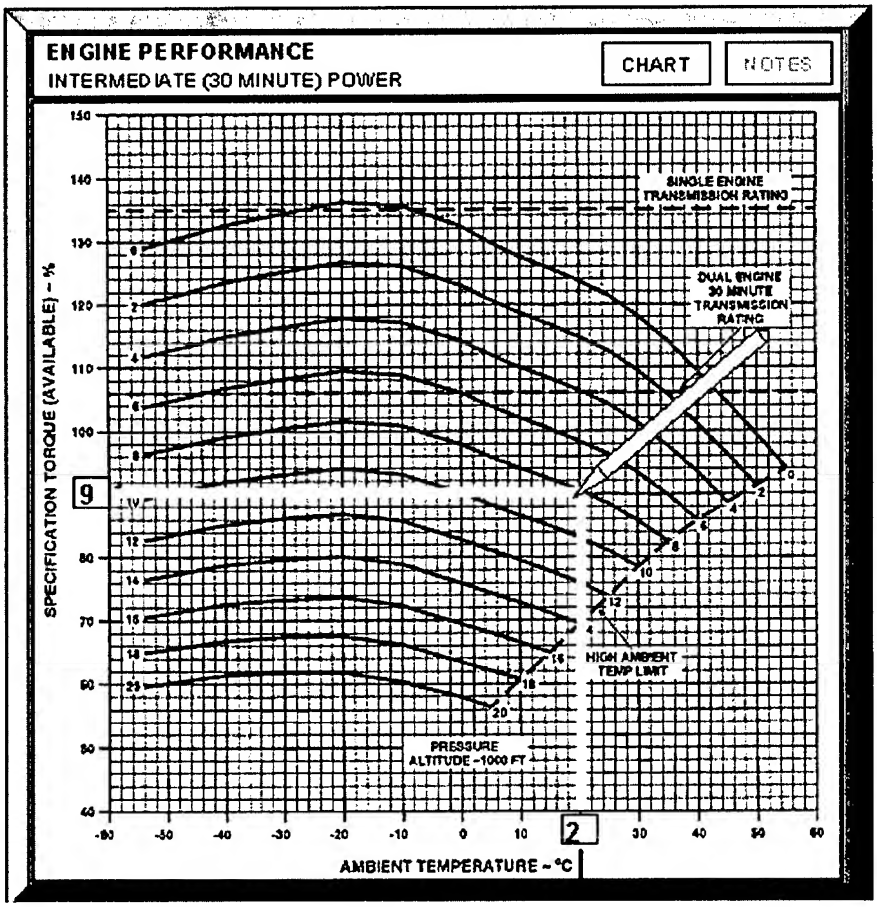

Figure 21. Axis Line Highlighting Concept

<u>Concept PC5</u>

The final performance chart concept that we presented to the pilots is shown in Figure 22. In this example, we maintain the idea of axis lines providing information to the pilot, but we have also included a different concept for including information about the parameter curves within the chart. As opposed to using a magnifying glass feature to get detailed information about the parameter, we have simply used a highlighting feature. In addition to the axis line feature described in other concepts, parameter curve information is also provided to the pilot. When the pilot moves the stylus, the axis line highlighting changes automatically to indicate the corresponding x and y values on each axis. Also, the parameter curve that is located most closely to the stylus is highlighted to give the pilot an easy and quick description of each parameter of interest within the chart.

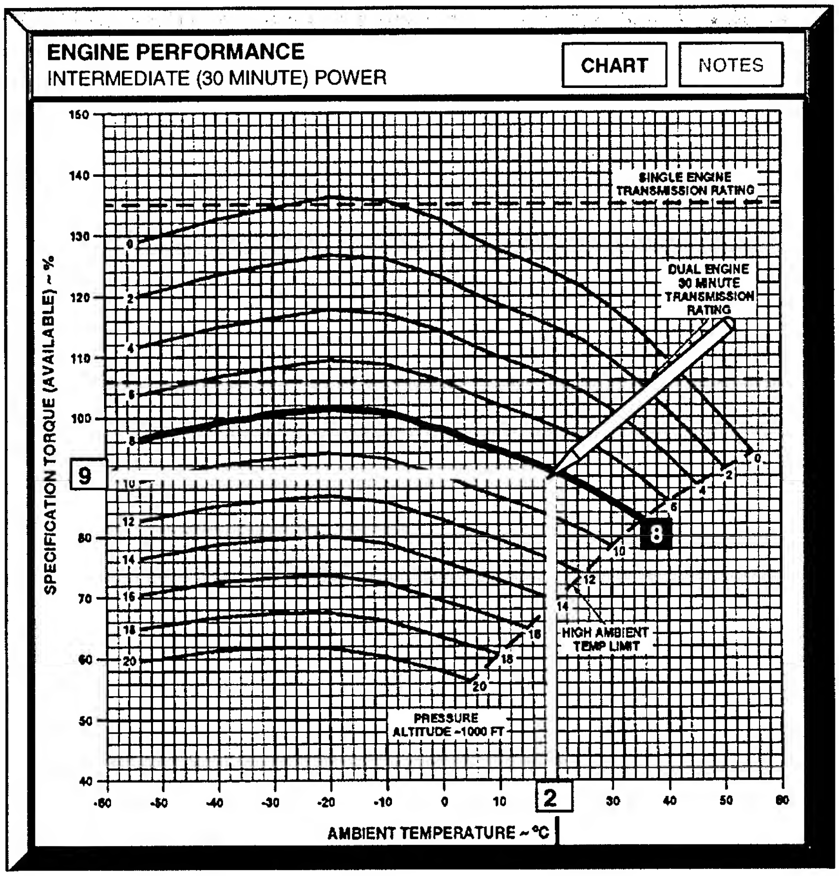

Figure 22. Axis Line/Parameter Curve Highlighting Concept

3.5.3.2 Wind Envelope Charts. The other type of graphical images that were noted as used quite frequently were wind envelopes. Wind envelope charts are presented in the PCL and do not appear in paper NATOPS manuals. A wind envelope chart is used to indicate the range of good/ideal wind conditions (speed and direction) that are acceptable during a hover over the ship.

Each wind envelope is specific to a particular ship and includes wind envelopes for both day and night landing. Other parameters that are indicated on a wind envelope chart are RAST vs. non-RAST capable, port vs. starboard vs. stern approaches, and whether or not SAS boost is engaged or not. Wind envelope charts in the PCL also present day and night envelopes overlaid on each other on the same chart with shading being the only differentiating factor between them. It was difficult at first glance to determine which envelope corresponded to daytime landings and which corresponded to nighttime landings. Also, for a given ship type, the envelopes for the type of approach that was being taken appeared on different pages of the manual, thereby making it difficult at times to find the appropriate envelope that was required. The concept that we have developed integrates these factors into one display and allows the pilot to simply select a set of parameters that control the type of envelope that will be displayed.

Concept WE1

In Figure 23, you can see an outline of the ship in addition to a "parameter selection" area. The pilot would select the "Ship Type" via a drop-down menu that would include information for each type of ship that is listed in the PCL. The pilot would also select specific parameters from the parameter selection area that correspond to the type of information they desire. These parameters control the graphical representation of the figure on the left side of the display. Once the parameters are selected, the figure would be automatically updated with the information supplied by the pilot and the correct envelope would be displayed.

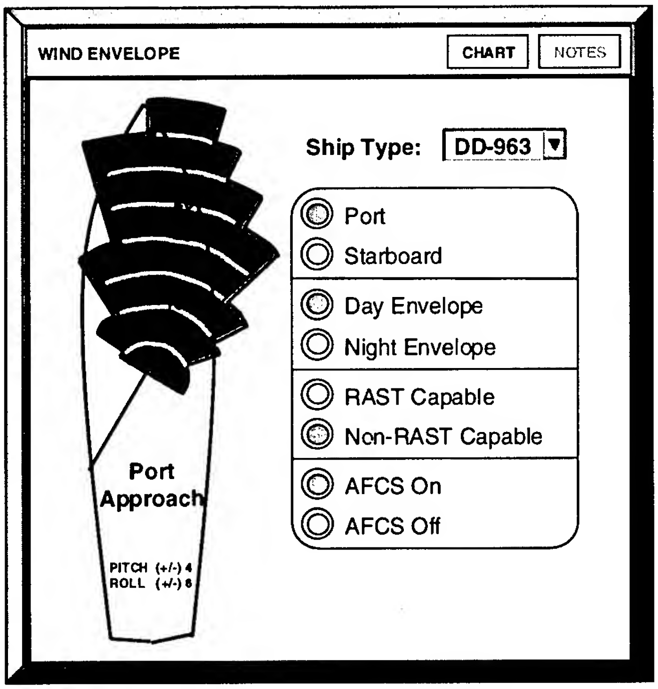

Figure 23. Wind-Envelope Chart Concept

3.5.4 Interview Feedback and Recommendations

The pilots were asked to comment on particular features of each of the concepts, indicating things that were useful and also identifying those features that were not useful. They were then asked to focus on to a particular concept or small set of concepts that they felt would provide them with the easiest access to the types of information that they need. For this discussion, we will break the responses into categories relating to performance charts and those relating to wind envelope charts.

Performance Charts

Every pilot felt that the best, and most useful, concept was Concept PC5 (axis lines plus parameter curve highlighting). They felt that this type of display provided them with the all of the values that are of interest to them when they are interacting with a performance chart. Each pilot liked the idea that all important parameters are quickly available and

felt that the feedback provided to them through the use of highlighting would allow them to immediately determine the particular value for which they were looking.

Some pilots felt that it was unnecessary to highlight the entire parameter curve for Concept PC5. They felt that you might be able to simply drop a digital value of the parameter curve off from the tip of the stylus. An example of this is displayed below in Figure 22.

Some pilots felt that the magnification concepts, particularly PC3 (magnification with axis line highlighting) *could* be useful in situations where you need precise information about the parameter curves. In addition, some pilots felt that, for some charts, having a magnification lens might make it much easier to differentiate between lines, especially when the parameter curves converge to a common location. However, even the pilots that liked the magnification lens concept felt that if it were included in a graphics interaction tool, it should be a selectable feature and not something that would have to be used continually.

One of the factors that was mentioned as a disadvantage for the magnification lens concepts was related to the distortion that appears at the edges of the lens. Upon a quick glance at the chart, pilots felt it might be difficult to "follow" the parameter lines as they become distorted toward the edge of the lens based on the algorithms that were used to construct the magnification. This would be an issue that would need to be resolved if the magnification lens concept is pursued.

It was noted that the use of color is an important issue. There is no color standard that is currently used in these aircraft; however, pilots frequently use night-vision goggles and any color scheme must be conducive to use with these systems.

Some of the pilots liked the variety of features that were presented in these concepts. It was suggested that we might include a "display management configuration" menu that would include selectable parameters for chart interaction. This might include the ability to turn on and off features like magnification, axis highlighting, parameter curve highlighting, etc.

Based on the feedback from the pilots and the scope of the project, the most widely accepted concept was chosen (Concept PC5) for further development and was modified to accommodate some of the recommendations that were provided by the pilots. The resulting interface is presented below in Figure 24.

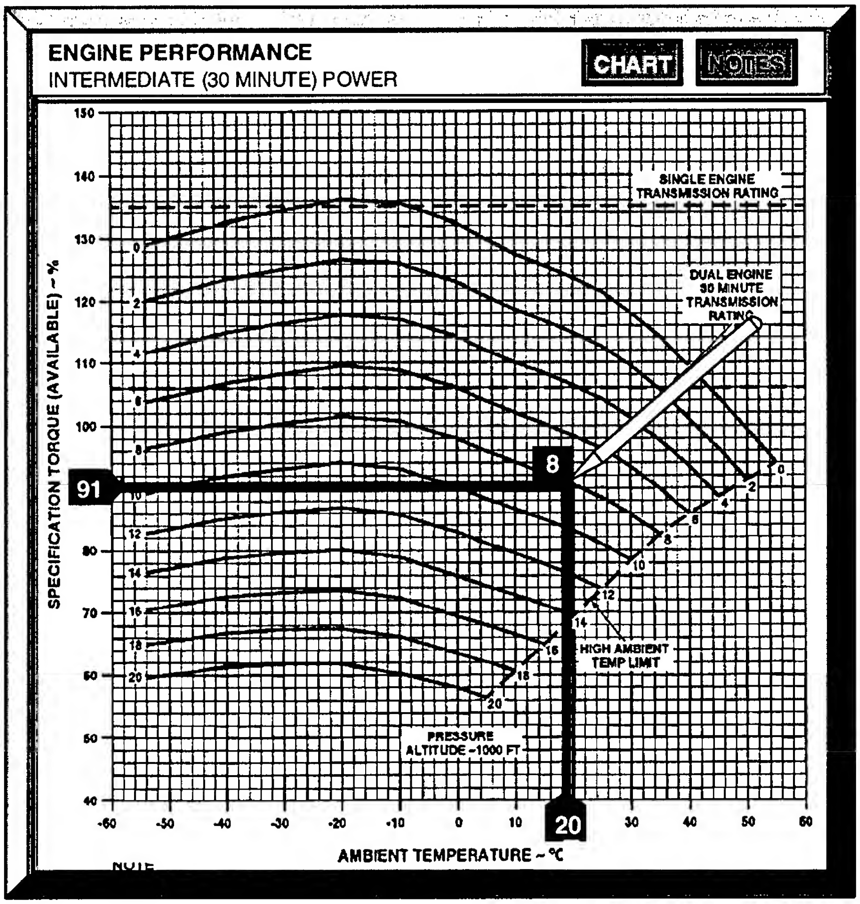

Figure 24. Recommendation for Performance Chart Graphical Interaction Concept

Wind Envelope Charts

Every pilot felt that the wind envelope concept, as it was presented, would be very useful during flight.

It was recommended that salient text information be presented at the top of the chart on the chart view for reference purposes to indicate the type of ship and the deck-type on which the aircraft was landing.

All pilots mentioned that "STERN" should be included in the parameter selection portion of the display to provide wind envelope information for Stern approaches to the ship. It was noted that there should be some intelligence built into the interface. For example, some ships are only Non-RAST capable and for those types of ships the parameter should simply default to "Non-RAST."

There were some recommendations about possible redesigns of the interface. Many of these centered on desirable feedback to present to the pilot about current parameter selections. It was suggested that, instead of a radio button technique for the pilot to select particular parameters, an alternative drop-down menu containing the possible selections be used instead. This would provide immediate feedback to the pilot about the particular

set of selected parameters that would be preferable to relying solely on whether the circle next to the parameter was filled (selected) or not (not selected).

Based on the recommendations from the pilots, the wind envelope interface was redesigned and the resulting concept is presented below in Figure 25.

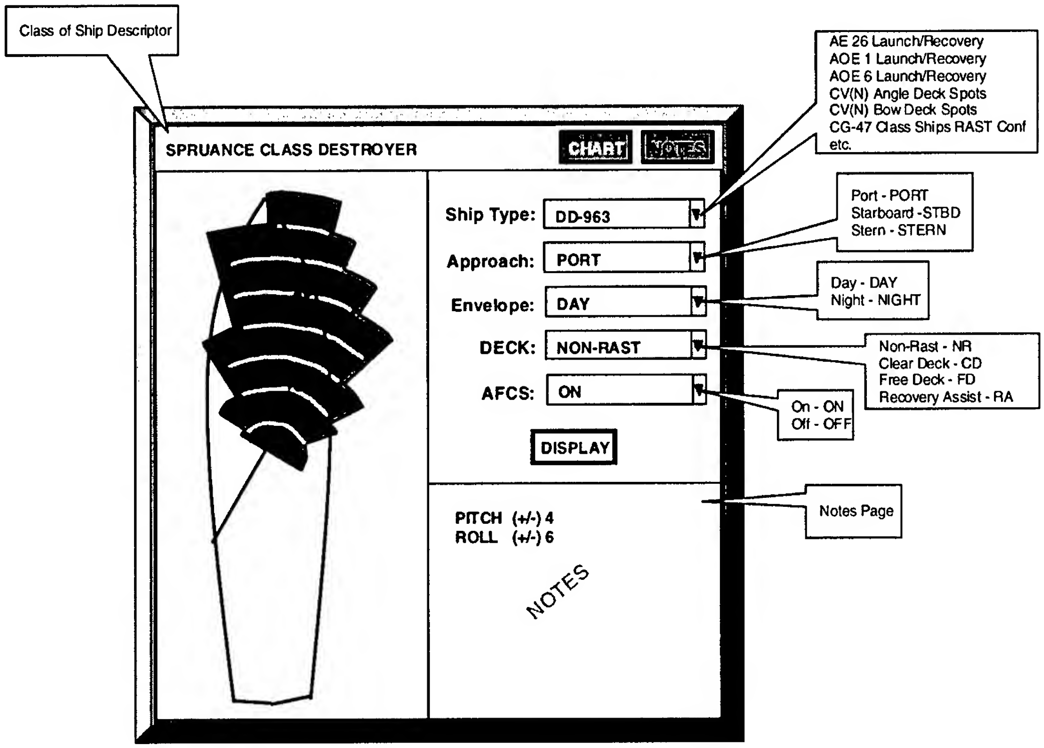

Figure 25. Recommendation for Wind Envelope Graphical Interaction Concept

4. Discussion

4.1 Main Effects

The benchmark evaluation experiments were conducted to provide an initial assessment of whether aviator performance would differ dependent on the search tool that was used – traditional paper NATOPS/PCL or an electronic version of these tools (IE-NATOPS). The results from these experiments provide preliminary evidence that aviator performance may differ dependent on the search mode, as well as the exact purpose of the search. For example, within experiment 1, content-access trials measured the participants' other-directed access of information in the paper NATOPS/PCL and the IE-NATOPS. The participants knew where they were starting and what they had to find in these documents, and they simply had to navigate to the designated information. Under these conditions, results indicate that access times to reach a given page of information were significantly faster for IE-NATOPS than for the paper NATOPS/PCL. This improvement in other-directed access time with IE-NATOPS over the paper NATOPS and PCL suggests that, when participants know what kind of information they are seeking, IE-NATOPS is a faster means to access that information than the paper NATOPS/PCL.

A slightly different picture was seen in the second study where self-direct search rates were examined. In experiment 2, problem-solving trials were used to measure the participants' self-directed search time and accuracy for resolving problem scenarios using the paper NATOPS/PCL and IE-NATOPS. Results indicate that, overall, there was not a significant difference in self-directed search time and accuracy between the paper NATOPS/PCL and IE-NATOPS. This null difference between NATOPS/PCL formats during the self-directed search process implies that the IE-NATOPS format of the NATOPS and PCL may provide equivalent support for situations in which aviators know the general section they must access, but do not know the specific sections of the paper format. For within these situations, search times are tapping not only search rates, but are also dependent on the variations in search strategies that individuals may adopt.

Although the studies contained within the benchmark evaluation were not intended to provide specific information of how context may impact which search tool is most effective, they may provide a clue. Sequential search problems within the study examining access time were designed to be non-equivalent in that they grew progressively more complex to ensure that participants had an adequate knowledge of how to manipulate the interface before moving on to more difficult cases. As the specific effect of individual searches was not the focus of the current benchmark, no specific hypotheses were made in this regard. Post-hoc analyses indicated that there were differences among the scenarios, with most favoring IE-NATOPS, but we believe that the differences found were primarily in the complexity of the searches.

Problem solving scenarios, within experiment 2, were originally intended to sample a variety of information types and be uniform in their complexity. A panel of SMEs who reviewed these scenarios before the data collection effort took place felt that the

complexity of the scenarios was uniform across the set. The experimenters' observations during data collection, however, revealed that there seemed to be some scenarios that caused participants to have longer decision and access times than other scenarios. Additionally, there seemed to be some characteristics of the scenarios that consistently favored either the paper-based NATOPS/PCL or IE-NATOPS. For example, when participants were required to use performance charts, search times/problem solutions were quicker using the electronic search tool (IE-NATOPS). In addition, when completing checklists where hyperlinks were inserted in IE-NATOPS, the electronic search tool seemed to produce quicker search times. Conversely, it appears that scenarios that required participants to search for diagrams or charts lent themselves to the paper search tool rather than the electronic version. In many instances it appeared that participants, while knowing the general section where required information could be found, did not know the specific subsections. The paper search tool would seem to make it easier to find information in this situation (easier to scan), especially something that would stand out like a chart or graphic.

Given that the aviators who participated in this benchmark evaluation of IE-NATOPS had less than one hour of training on IE-NATOPS, and given that the aviators were highly experienced in the use of the paper NATOPS and PCL for accessing information to resolve problem scenarios, the results from the content access trials and problem solving trials are indicative of a system that may prove to be superior to the existing method of accessing NATOPS data in the aircraft. Since the IE-NATOPS used for this benchmark evaluation is a *prototype* system, there is the potential for further improvements in the interface, possibly resulting in improvements in access times – which are already faster than the paper NATOPS and PCL – and decision support.

Additionally, though this benchmark evaluation was not intended to do so, the results of this study suggest that there may be characteristics of scenarios that may favor the paper-based NATOPS and PCL information, the current version of IE-NATOPS, or have no format bias. Although results/trends of the current study may be argued to suggest that scenario/situational characteristics may impact the gains from an electronic versus paper search tool, the limitation of the current study is that it was not designed to examine this question. Therefore, any noted trends are based on observation, combined with a post-hoc analysis of scenario content. Despite this limitation, this implication is significant in that, as far as the authors are aware, there is no research in the published literature that has addressed the characteristics of scenarios and their interaction with paper versus electronic forms of NATOPS and PCL. If NATOPS and PCL data displays prove to be similar in terms of human performance to the moving map display, it may be possible to eliminate the bias of one format over the other by development and application of interface elements. A study designed to manipulate the characteristics of scenarios and their interaction with the information format and participant knowledge and experience is necessary to establish these characteristics and associated interactions. Once these characteristics and interactions are established, the results may be applied to the design of the NATOPS and PCL interfaces to negate any biases in the majority of scenario characteristics and user experience.

4.2 Study Limitations

A potential limitation of this exploration of scenario characteristics with the current study is that the participants were all aviators with extensive experience using the paper NATOPS and PCL. In addition, the participants' experience with the specific information types and content was not controlled. Likewise, the scenarios were not designed to vary specific information types and content with interface type. The limitations of the benchmark evaluation introduce sources of variability that remain unaccounted for by the design of the current study, affecting the ability to unambiguously establish the scenario characteristics favoring one or both of the NATOPS and PCL interface types. These limitations do not affect the primary purpose of this benchmark evaluation, however. The external/other and internal/self directed access times for IE-NATOPS and their comparison to the paper-based NATOPS and PCL were clearly established.

4.3 Graphics Evaluation

The scenarios in the benchmark evaluation did not allow for systematic variation of the electronic graphical images like charts of schematics that the participating pilots used during their data searches. To address interaction issues with electronic graphics we interviewed the pilots after the benchmark evaluation. As mentioned earlier, we presented a variety of interaction methodologies to the pilots for interacting with performance charts and simply solicited feedback from each pilot on each of the concepts. In general, the results of the interviews suggested that pilots felt the techniques used when interacting with graphics are very important to the usefulness of the IE-NATOPS system. Due to the small size of the targeted IE-NATOPS display, pilots felt that the ways in which they interacted with graphics in the paper NATOPS manual would not be adequate when a performance chart was reduced in size. More specifically, every pilot felt that the best, and most useful, concept was dynamic labeling. They felt that this type of display provided them with all of the values that are of interest when they are interacting with a performance chart. Each pilot liked the fact that all important parameters are quickly available and felt that the feedback provided to them through the use of highlighting and labeling would allow them to immediately determine the particular value for which they were looking. However, some pilots felt that it was unnecessary to highlight the entire parameter curve. Some suggested that the value of the parameter simply be displayed off the tip of the stylus to limit the spread of information within the display.

Some pilots felt that dynamic magnification *could* be useful in situations where you need precise information about the parameter curves or where parameter curves converge to a single point. However, the pilots mentioned that typically they use performance charts to "eye-ball" particular trends or system performance information. Because of this, many of the pilots felt that such a feature would result in a display that was too cluttered and somewhat difficult to use. Some of the pilots, on the other hand, felt that for specific types of charts (e.g., complicated charts with many parameters), there might be some utility of dynamic magnification. In future designs of the graphical interaction tools, this

could be a selectable feature and not necessarily always present during interactions with the performance chart. We plan to use the information gathered in this evaluation to further refine the concepts that were presented to the pilots in this test.

4.4 The Future

4.4.1. Future Research

While the benchmark evaluation of the prototype IE-NATOPS indicated that the potential is there for IE-NATOPS to produce quicker access times, as well as processing times, the strength of these relationships seemed to vary, depending on the characteristics of targeted scenarios. As the current study was not designed to examine the effect of search mode on scenario characteristics, results regarding specific scenario effects are post-hoc and must be taken in light of the limitations imposed with respect to the specific scenario effects that have been noted. Future research should design empirical studies to systematically investigate what characteristics might favor the use of IE-NATOPS, as compared to traditional NATOPS/PCL. In addition, based on the results of the current study and comments from the aviators regarding the IE-NATOPS prototype system, the concept will be accordingly revised and improved. These future revisions should be empirically tested.

Regarding the graphical interaction techniques described in this paper, the recent proliferation of small handheld devices and PDAs suggests that it is imperative that basic research continue in the identification of novel and useful interaction methodologies for situations when large information spaces are presented on a small display surface. It is critical that future research continue this iterative approach (concept design, testing, redesign) so that the graphical interaction methodologies become intuitive, easy-to-use, and increasingly supportive of the needs of the pilot community.

4.4.2. Future Modifications/Directions

The findings from the benchmark evaluation have provided many areas in which the design/interface of IE-NATOPS may be able to be modified such that the benefits of this tool are further enhanced. The primary source of suggested changes in the functionality or interface portions of IE-NATOPS came from the aviators who used the system in the benchmark evaluation (see section 3.4.1), although experimenters also noted a few suggestions based on observing aviator interaction with the system.

One example of a possible improvement to the design of the IE-NATOPS interface that could further enhance access times – particularly when self-directed – and possibly enhance decision-making times over and above those of paper NATOPS and PCL involves the method of accessing subsections in each section of NATOPS and PCL. In the version of IE-NATOPS employed in this study, participants had to select each individual subsection they wished to view. The participants had to back out of a subsection, then select the next subsection they wished to view. When the participants did not know the exact location of an item, this method of navigating IE-NATOPS may

have resulted in poorer search times than were possible with the paper NATOPS and PCL. Thus, by allowing the participants to select and/or scroll through the subsections of IE-NATOPS, search times could be improved. Using this scrolling method, IE-NATOPS would be like a web page that uses hyperlinks (the IE-NATOPS index) and hypertext for sections of the page, allowing the user to jump to a section of the page and then scroll backwards and forwards starting at that location.

Another possible modification might involve the following. Since a paper version of NATOPS and the PCL will be carried in aircraft for many years to come, it is imperative that IE-NATOPS and paper NATOPS and PCL should use similar organization and navigation cues for information contained therein. Accordingly, a comprehensive index that is meaningful (to the *users*) and with accurately placed tabs or other quick-reference cues, and a consistent layout and means of control of information across sections should be employed.

IE-NATOPS has potential uses not only as a decision-aid while in the cockpit, but also as a training tool that can be implemented in support of current NATOPS training procedures. As the tool is electronic, it represents a more portable training reference as well as a method to support delivery of training via the design of event-based scenarios in which certain competencies dealing with IE-NATOPS are targeted. This would allow targeted practice and feedback to be built into the system to augment the feedback given by the instructor(s). To pursue such training applications, a targeted analysis could be conducted of current NATOPS training procedures to: (a) identify strengths and weaknesses of the current method, (b) determine where IE-NATOPS may fit into the training rotation, and (c) the identify the competencies that should be addressed with this tool.

Further IE-NATOPS development efforts are warranted in both operational development and research. Operational development must be conducted to resolve issues in the areas of institutionalization, aircraft integration, and interface design. Institutionalization issues will include coordination with NATOPS committee members and the Naval Air Systems program office for training systems (PMA 205) to identify concept issues related to training and to integration of the IE-NATOPS into the NATOPS creation and update process. Flight evaluations of a certified IE-NATOPS system will be required to address aircraft integration and interface design issues. Future research efforts will be required to develop HUMS diagnosis logic for cockpit alerting and tools to interact with graphics on small screens. Research can also be conducted to investigate alternative tools for performance data calculations and checklist interface features.

5. References

Askwall, Susanne (1985) "Computer supported reading vs. reading text on paper: A comparison of two reading situations." *International Journal of Man-Machine Studies*. 22(4), p.425-439.

Boorman, d. (2000). Reducing flight crew errors and minimizing new error modes with elecronic checklists. *Proceedings of the International Conference on Human-Computer Interaction in Aeronautics* (pp. 57-63). Toulouse: Cepadues-Editions.

Bowers, C., J. Deaton, R. Oser, C., Prince, & M. Kolb (1995) Impact of automation on aircrew communication and decision-making performance. The International Journal of Aviation Psychology, 5(2), 145-167.

Byington, C., M. Yukish, E. Scheie, F. Glenn, J. Deaton, & J. Dickieson (1999) Evaluation of Human-Machine Interfaces for Aircrew Fault Diagnosis and Management. In Proceedings of the International Condition Monitoring Conference. Swansea, Wales: University of Wales.

Campbell, R., Garga, A., McClintic, K., Lebold, M., Byington, C., & Glenn, F. (2001) Pattern Recognition for Fault Classification with Helicopter Vibration Signals. Proceedings of the Annual Meeting of the American Helicopter Society – AHS International Forum 57. May 9-11, 2001.

Deaton, J., Burke, C., & Good, M. (2000). *Final Report: IE-NATOPS Knowledge Elicitation Effort*. CHI Sysems, Inc. Technical Report. CHI Systems, Inc., Orlando, FL

Deaton, J., F. Glenn, P. Federman, G. Nickerson, C. Byington, R. Malone, R. Stout, R. Oser, & R. Tyler (1997a) Aircrew Response Procedures to Inflight Mechanical Emergencies. In Proceedings of Human Factors Society 41st Annual Meeting, Santa Monica, CA: Human Factors and Ergonomics Society.

Deaton, J., F. Glenn, P. Federman, G. Nickerson, C. Byington, R. Malone, R. Stout, R. Oser, & R. Tyler (1997b) Mechanical Fault Management in Navy Helicopters. In Proceedings of Human Factors Society 41st Annual Meeting, Santa Monica, CA: Human Factors and Ergonomics Society.

Deaton, J., Glenn, F., Popp, E., Barba, C., & Bowers, C. (1998) Investigation of Aircrew Information Requirements for Mechanical Fault Warnings. (CHI Systems Technical Report 981123.9803) Lower Gwynedd, PA: CHI Systems, Inc.

Degani, Asaf, & Wiener, Earl L. (1990) "Human Factors of Flight-Deck Checklists: The Normal Checklist." *NASA Contractor Report 177549.*

Frey, P.R., Rouse, W.B., & Garris, R.D. (1992). *Big graphs and little screens: Model-based design of large scale information displays*. Technical Report (STI-TR-8817-006). Office of Naval Research, Arlington, VA.

Garga, A., Campbell, R., Byington, C., Kasmala, G., Lang, D., Lebold, M., & Glenn, F. (2001) Diagnostic Reasoning Agents Development for HUMS Systems. Proceedings of the Annual Meeting of the American Helicopter Society – AHS International Forum 57. May 9-11, 2001.

Glenn, F., Federman, P., Deaton, J., Byington, C., Malone, R., Archer, R. (1997) Development of Onboard Diagnostics Interface: Interim Report. Lower Gwynedd, PA: CHI Systems, Inc.

Gould, J., Alfaro, L., Barnes, V., Finn, R., Grischkowsky, N., & Minuto, A. (1987) Reading is Slower from CRT Displays than from Paper: Attempts to Isolate a Single Variable Explanation. Human Factors, Vol. 29, No. 3, pp. 269-299.

Kinnear, P., & Gray, C. (1997). *SPSS for windows made simple.* East Suffex, UK: Psychology Press.

Mosier, Kathleen L., Palmer, Everett A., Degani, Asaf (1992) "Electronic checklists: Implications for decision making." *Proceedings of the Human Factors Society 36th Annual Meeting.* p.7-11.

Palmer, Everett, & Degani, Asaf (1991) "Electronic checklists: Evaluation of two levels of automation." *Proceedings of the Sixth Symposium on Aviation Psychology.* p.178-183.

Rice, Gary E. (1994) "Examining constructs in reading comprehension using two presentation modes: Paper vs. computer." *Journal of Educational Computing Research.* 11(2), p.153-157.

Appendix A. Participant Briefing

Participant Briefing: IE-NATOPS Benchmark Evaluation Effort

The goal of this project is to investigate an interface concept for an interactive electronic NATOPS (IE-NATOPS) to support aircrew performance. This study represents a benchmark evaluation of the prototype IE-NATOPS. This study will compare aircrew performance when using the traditional paper copy of NATOPS and PCL with that of an electronic version presented via a computer interface. Results from this study will be used to refine the IE-NATOPS concept.

If you choose to participate in this experiment today, you will be introduced to the IE-NATOPS interface and given the opportunity to practice using it. You will then be asked to work through a number of scenarios in which the NATOPS and PCL, or IE-NATOPS will be made available for use. Specifically, you will be asked to resolve a number of problems in each scenario using the different versions of NATOPS. We will be collecting data on how you go about resolving the problem scenarios, how long it takes to reach a solution, and the outcome of your solution.

There are no foreseeable risks to you by participating in this research. At times, you may feel a small amount of stress similar to what you may have felt during your annual NATOPS test. All data are collected anonymously, such that there is no way of identifying a particular participant with his or her scores or responses on the questionnaires.

Your participation in this experiment is voluntary. You may terminate your participation at any time without any adverse consequences. If you need any additional information about this experiment, please contact:

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Appendix B. Privacy Act Statement

Privacy Act Statement

1. Authority. 5 U.S.C. 301

2. Purpose. The use of NATOPS and PCL by naval aviators to resolve paper-based problem scenarios will be evaluated using methods outlined in the study titled: "Condition Based Maintenance: Benchmark evaluation effort supporting development of an electronic NATOPS manual for the H-60." This study is to be performed in an attempt to understand if differences exist in the processes used by naval aviators when using traditional paper-based NATOPS and PCL with that of an electronic version currently implemented by the Interactive Electronic NATOPS project (IE-NATOPS).

3. Routine Uses. The data collected will be used for analyses and reports by the Departments of the Navy and Defense, other U.S. Government agencies, and authorized government contractors. Additional use of the information may be granted to non-Government agencies or individuals by the Navy Surgeon General following the provisions of the Freedom of Information Act or contracts and agreements. I voluntarily agree to its disclosure to the agencies or individuals identified above, and I have been informed that failure to agree to this disclosure may make the research less useful.

Appendix C. Informed Voluntary Consent to Participate

Informed Voluntary Consent To Participate:
IE-NATOPS Benchmark Evaluation Effort

1. I am being asked to voluntarily participate in a data collection effort titled, Benchmark evaluation effort supporting development of an interactive electronic NATOPS manual for the H-60.

2. During the research, I will resolve paper-based problem scenarios using paper-based and electronic NATOPS and PCL, and participate in a short de-brief on my experiences subsequent to the session. Portions of this session may be audio-taped to assist in later data analysis. However, all collected information will remain confidential and anonymous and will not impact you in any way.

3. I understand that the investigators believe that the risks or discomforts to me are as follows:

    - *No greater than would be experienced during the participation in a typical School house class*
    - *No greater than would be experienced during responding to a typical Navy survey.*
    - *No greater than would be experienced while performing my annual NATOPS test.*

4. The benefits that I may expect from my participation in this study are minimal. I understand that I will receive no direct benefit other than the knowledge that participation in this study will aid efforts to improve the performance, safety, and/or effectiveness of the US Navy.

5. My confidentiality during the study will be ensured by assigning me a coded identification number. My name will not be directly associated with any data. The confidentiality of the information related to my participation in this research will be ensured by maintaining records only coded by identification numbers. Video and photographic images of me will not be published or displayed without my specific written permission.

6. If I have questions about this study I should contact the following individuals:

    Randall L. Oser
    Naval Air Warfare Center Training Systems Division, AIR 4961
    Orlando, Florida 32826-3275
    (407) 380-4818
    OserRL@navair.navy.mil

7. My participation in this study is completely voluntary.

8. No additional out of pocket costs to me may result from my voluntary participation in this study.

9. Official government agencies, such as the Naval Bureau of Medicine and Surgery, may have a need to inspect the research records from this study, including mine, in order to fulfill their responsibilities.

10. I have received a statement informing me about the provisions of the Privacy Act.

11. I have been informed that the Process Administrator is responsible for storage of research records related to my participation in this data collection effort. My consent form will be stored under lock and key in compliance with NAWCTSD Instruction 3900, Protection of Human Subjects (Pending).

12. I have been given an opportunity to ask questions about this study and its related procedures and risks, as well as any of the other information contained in this consent form. All my questions have been answered to my satisfaction. I understand what has been explained in this consent form about my participation in this study. I do not need any further information to make a decision whether or not to volunteer as a participant in this study. By my signature below, I give my voluntary informed consent to participate in the research as it has been explained to me, and I acknowledge receipt of a copy of this form for my own personal records.

Volunteer Signature	Name	SSN	Date
Principal Investigator Signature	Name	SSN	Date

Appendix D. Biographical Information

Biographical Information

Rank/Rate: ________

Sex: M ______ F ______

Age: ________

Squadron: ________ Time in squadron: ________(months)

Time in Service (months): ________ # of Deployments: ________

Current Assignment (e.g., OPS, OPSO, SKEDS): __________________

Past Assignments:

____

Special Qualifications (e.g., NATOPS Instructor, ASST NATOPS Instructor, FCP, SWTI, Instructor duty,
Test Pilot, etc.):

____

Time in *Present* Assignment: ________(months)

Time in *Previous* Assignment: ________(months)

Aircraft	Hours (approx.)	Role [1]	Aircraft	Hours (approx.)	Role [1]
HH-60F	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______

Approx. time in H-60F over:

Last 30 days: ______ Last 60 days: ______ Last 90 days: ______

Approx. time in H-60H over:

Last 30 days: ______ Last 60 days: ______ Last 90 days: ______

Approx. total time in H-60F Simulator: ___________(hours)

Total Time in Rotary Wing: ________(hours)

Total Flight Time: ________(hours)

Approx. hours of use of desktop/laptop personal computers per week: _________(hours)

Approx. hours of use of PDA or other handheld computing device per week:
_______(hours)

[1]*: e.g., indicate whether hours were obtained as helicopter commander.*

Appendix E. Post-Experiment Questionnaire

POST-EXPERIMENT QUESTIONNAIRE

The purpose of this questionnaire is to provide you with a means to comment on issues regarding the IE-NATOPS and the experiment in which you have just participated. As with the data collected during the experiment, your comments on this questionnaire will remain confidential.

This questionnaire contains *12* questions. Select your response from the response items provided. Make your selection by circling the letter for that selection. If you would like to elaborate on any of your responses, you may do so in the space provided. If you have any questions regarding any items in this questionnaire, feel free to ask the experimenter for clarification.

1. IE-NATOPS training organization was...

    (a) ...too loose. I needed more structure in the training program.
    (b) ...perfect for my needs.
    (c) ...too regimented. I needed to be able to control the pace and direction of my study more than I was allowed.

Comments:

2. IE-NATOPS training contained...

    (a) ...little I needed to learn to use the system to resolve the problem scenarios.
    (b) ...sufficient content to learn to use the system to resolve the problem scenarios.
    (c) ...more than I needed to learn to use the system to resolve the problem scenarios.

Comments:

3. IE-NATOPS training contained...

    (a) ...too little practice time.
    (b) ...sufficient practice time.
    (c) ...too much practice time

Comments:

4. IE-NATOPS training scenarios were…

   (a) …too easy.
   (b) …sufficiently complex.
   (c) …too complex.

Comments:

5. Confidence regarding your use of IE-NATOPS for acquiring information *in flight*:

   (a) Very confident. I can go directly to information I need to access in the system without having to search for the item(s).
   (b) Confident. I can find information I need to access in the system in a timely manner.
   (c) Uncertain. I might be able to find information I need to access in the system in a timely manner.
   (d) Very uncertain. I probably won't be able to find information I need to access in the system in a timely manner.

Comments:

6. The interface was physically easy to manipulate.

NATOPS	IE-NATOPS
(a) Strongly agree	(a) Strongly agree
(b) Agree	(b) Agree
(c) Neutral	(c) Neutral
(d) Disagree	(d) Disagree
(e) Strongly disagree	(e) Strongly disagree

Comments:

7. I never had a doubt as to what I had to do to the interface to access data.

NATOPS	IE-NATOPS
(a) Strongly agree	(a) Strongly agree
(b) Agree	(b) Agree
(c) Neutral	(c) Neutral
(d) Disagree	(d) Disagree
(e) Strongly disagree	(e) Strongly disagree

Comments:

8. I had no trouble reading and understanding the NATOPS data.

NATOPS	IE-NATOPS
(a) Strongly agree	(a) Strongly agree
(b) Agree	(b) Agree
(c) Neutral	(c) Neutral
(d) Disagree	(d) Disagree
(e) Strongly disagree	(e) Strongly disagree

Comments:

9. I had no trouble finding data I needed to use to resolve the scenarios.

NATOPS	IE-NATOPS
(a) Strongly agree	(a) Strongly agree
(b) Agree	(b) Agree
(c) Neutral	(c) Neutral
(d) Disagree	(d) Disagree
(e) Strongly disagree	(e) Strongly disagree

Comments:

10. It was easy to access information that involved searching in multiple sections.

NATOPS	IE-NATOPS
(a) Strongly agree	(a) Strongly agree
(b) Agree	(b) Agree
(c) Neutral	(c) Neutral
(d) Disagree	(d) Disagree
(e) Strongly disagree	(e) Strongly disagree

Comments:

11. For each of the following aspects of the IE-NATOPS please indicate your agreement with the following statement regarding their ease of use. Ease of use is defined as the degree to which it was easy to manipulate the interface to find the information that was needed. Indicate your level of agreement by putting an "x" in the appropriate box.

"I found that this function was easy to use."

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
History Function					
Bookmark Function					
Navigation Keys (Forward/Backward)					
Tab Feature Within Checklist Section					
Search Feature Within NATOPS Section					
Performance Charts					

Comments:

12. For each of the following aspects of the IE-NATOPS please indicate your agreement with the following statement. Indicate your level of agreement by putting an "x" in the appropriate box.

    "I would expect this function to be functional (useful) within an operational environment (in the aircraft)."

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Bookmark Function					
Performance Charts					

Comments:

Appendix F. Participant Debriefing

PARTICIPANT DEBRIEFING

The study in which you have just participated is being performed in an attempt to understand if differences exist in the processes used by naval aviators when using traditional paper-based NATOPS and PCL compared to a prototype interaction electronic NATOPS (IE-NATOPS). The study compares aircrew performance when using the traditional paper copy of NATOPS and PCL with that of an electronic version presented on a computer interface. Results from this study will be used to refine the IE-NATOPS concept.

The purpose of the IE-NATOPS project is to facilitate the in-flight decision-making processes requiring NATOPS data. By making improvements to the organization, presentation, and accessibility of the NATOPS data, it is anticipated that more timely resolution of systems and performance related problems occurring in flight may result than is observed with the current paper-based NATOPS format.

This study represents a benchmark evaluation of the prototype IE-NATOPS. The study is a continuation of the work that has been conducted in developing an electronic format for NATOPS in the H-60 rotorcraft. The major players in this effort have included the Naval Air Warfare Center Training Systems Division (NAWCTSD), the Office of Naval Research (ONR), the University of Central Florida, CHI Systems, Inc., and Honeywell Technology Center.

If you have any further questions, or if you would like to learn the results of this study upon its completion, please contact:

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Appendix G. IE-NATOPS Training

<u>G.1 IE-NATOPS Training Protocol</u>

IE-NATOPS TRAINING (Do not read)

The next section of the study will require you to utilize an electronic version of NATOPS. However, prior to this we are going to conduct a short training session so that you feel comfortable operating this electronic version. Training will proceed in the following manner. First, I will briefly explain the general features of the IE-NATOPS (basically the layout of the initial screen). Then I will progress to describing the features of each of the main six modes (checklist, trends, data, alert, NATOPS, notes) as well as how to navigate within these modes. Finally, we will conclude with several hands on practice sessions in which you will use the IE-NATOPS to locate various information. The information that you will be required to find within these practice sessions will be similar to the information that the paper based scenarios will require you to access within the actual study. This process will be highly interactive so if at any time you have questions, please feel free to ask.

I GENERAL INFORMATION (DO NOT READ)

In many ways the electronic version (IE-NATOPS) is configured similarly to the paper NATOPS in terms of organization of content. The main differences are: (1) many sections contain hyperlinks (identified by blue text, clicking on it will take you to another section – replace "go to" sections in paper NATOPS, and (2) that the navigation within sections (e.g., checklist, trends, data, alert, NATOPS, notes) is most akin to that of an internet browser.

Instructor: At this point pull up IE-NATOPS...

We'll start with a general overview, hitting the high points concerning general navigation capabilities. Most of the navigation features will cut across the various aspects (checklists, NATOPS, performance data, etc. .) of the IE-NATOPS and as such will be further elaborated upon and practiced once we begin talking about each of the five sections of the IE-NATOPS.

Instructor: Interactively walk through each of the following points describing the general layout of the first screen accessed...

<u>General Navigation</u>

- First row of blue buttons (point) provide navigation through each of the 6 modes corresponding to checklists, trends, data, alerts, NATOPS, and notes. Only four are activated for use in the current version (checklist, data, NATOPS, and notes). To select a button click on it and the button will turn yellow to let you know its activated/selected.

Give the following quick explanation of each of the 6 modes as you click on it to show them that active button becomes yellow.

- o Checklist: Corresponds to information in PCL. No foldouts.
- o Trends: Not activated within this version.
- o Data: Calculation of performance information (done automatically versus how do it now – by hand)
- o Alerts: Not activated within this version.
- o NATOPS: Corresponds to information contained in paper NATOPS. No foldout charts…
- o Notes: Electronic notepad, probably not that useful within scenarios will be given today.

- Second row of blue buttons allow for navigation within (and between) screens, similar to an internet browser. Not all of the buttons are available for use within each mode (mode and situation dependent); if unavailable the text on the button will tend to gray out/unbold.
  - o For example, Fwd and PCL buttons currently grayed out.

Looking at the navigation tools, generally the following navigational tools are available within all modes: Back/Fwd, History, Bookmarks, the last button varies dependent on mode currently operating in (will be discussed in detail later). *Illustrate each.*

- o Back/Fwd: Operates same as back/fwd button on web browser. Each time you hit the back button it takes you back a step, while forward takes you forward. Notice that at this point the forward button is grayed out because we just started.
- o History: Let's you track your path of where you have been (e.g., what you have accessed thus far). Clicking on any item in the list will take you back to that section. Only contains a maximum of ten items, older items kicked out.
- o Bookmark: Operates same as does a bookmark within web/internet applications. Allows you to set bookmarks for frequently visited places. Again once bookmark set, click on it and it will take you back to that topic.
- o The last button on the right will change depending on the mode that you are currently in so we will wait and talk about that when we get into detail on each mode.

- The next large set of buttons allows the user to navigate through the information unique to each mode. In the checklist mode these larger buttons are yellow, however within NATOPS mode they are arranged like a Table of Contents. In either case if you click on one of these buttons a tree diagram will be revealed that further expands on the original topic. Once you begin to do this you will see a tree diagram that has either a "+" or "-" next to the topic of interest. Those will a

"+" can be further expanded by clicking on the "+" symbol. We'll play with this a little more later.

- Two smaller blue buttons on the bottom allow you to configure each screen when applicable. For example, it allows you to change the color of charts within the trend mode, modify screen for default configuration according for day, night, or NVG flights. The second button is an on-line help button. The on-line help button is not completed within this version and for the scenarios today you won't be required to use the configure button. Just wanted to give you a brief description.

II MODE SPECIFIC IE-NATOPS TRAINING (DO NOT READ)

CHECKLIST MODE

Function(s)

- The checklist mode is the default mode upon start-up and corresponds to the information contained within the PCL. As the checklist mode is currently active you will note that this button is currently yellow.
- As the checklist mode mimics the PCL, you will also see five blue buttons toward the bottom of the screen, corresponding to each of the major PCL sections/tabs (EP, NP, Special, Reference, Functional). Note functional checklist is not available within this version – grayed out.
- Furthermore, as the EP section is the default mode on start-up the EP button at the bottom of the screen appears depressed to indicate its active (look closely active button is surrounded by dotted lines). Single click on tab brings each of other sections up to front. Only one section is available at a time.

- Once a particular mode is activated the second row of buttons will indicate what navigational tools may be utilized within this mode. So within the checklist mode the following buttons are operational. Those not grayed out are available.
  - Back/Fwd: Same function as before (*illustrate*)
  - History: Same function as before (*illustrate*)
  - Bookmark: Same function as before (*illustrate*)
  - PCL: If active, indicates that there is at least one checklist that is still open and has not been fully completed. Checklist is fully complete when you have clicked upon the complete button at the bottom. Clicking on PCL will illustrate each open checklist. More later.

Getting to the Actual Checklist

- Large yellow buttons below (indicate) illustrate the first layer of information available within the checklist mode. Should correspond to similar sections of PCL. Clicking on the large yellow buttons will provide the user with a subset of checklists relevant to the category clicked upon within the main menu. Once you begin to do this you will see a tree diagram that has either a "+" or "-" next to the topic of interest. Those will a "+" can be further expanded by clicking on the "+" symbol. Those with a "-" are already expanded fully. Once checklists are fully expanded click on the specific checklist needed and it will appear.
- As you are progressing through a checklist can click on each step and a box will appear around it, letting you know that that particular step has been completed (good for keeping track of where currently are in case of disruption). Once you reach the end of the checklist it is important that you hit the "completed" button as this will close the checklist and kick you back into the next higher menu. *Illustrate this.*
- If you do not fully complete a checklist, but move on to another area the PCL navigational button will become active. The PCL button indicates that a checklist is still open. Clicking on this button will allow the user to see and access all checklists currently open (each will have its own tab, active one in yellow). *Illustrate.*
- Multiple checklists can be opened at once and each will have its own tab. User can switch between checklists by clicking on desired tab; active remains yellow, non-active blue.

<u>Moving around within checklists</u>

- Scroll button on right. For longer checklists you will notice a scroll button on the right. To scroll up or down can either click on the arrow at either end of the scroll button or can click and drag the gray bar at the right (bar in between the arrows at either end of scroll bar). To completely dismiss a checklist must click on the "Completed" button at the bottom of each checklist.
- For procedure steps that require another checklist, a hyperlink is provided. Hyperlink will be in blue; clicking on it will take you to hyperlinked section.
- Schematics, graphics, and tables – can double click to enlarge, although this function has not been made available on all schematics, tables, and diagrams as of yet.

Instructor: Ask to see if there are any questions up to this point.

TREND MODE

- Not applicable in this version.
- When inserted will give the user a graphical view of system performance during aircraft run up and shutdown operations.

DATA MODE

Functions

- Corresponds to an electronic calculation of performance data information that was formerly done by hand.
- Currently offers two types of electronic calculations — ability to maintain level flight (single engine) and range menu.

Layout/Navigation

- Navigation here works similar to that within the checklist mode (in regards to most buttons). Operation of first two rows of blue buttons and operation of mid-page yellow buttons remain the same.
- Within this mode there are two levels of yellow buttons: The first is the main menu (illustrate), while the second is a sub-menu (illustrate). Operate same as yellow buttons within checklist mode.

Actual Performance Calculations

- Once get into actual performance calculation screen (single engine level flight or range chart) you will see something that looks as follows:
    - On left will see boxes with PA, gross weight, and either OAT or fuel depending on calculation type.
    - To change the values currently in the boxes the user must use the keypad to the right. Simply click on the box on the left for which the value you want to change – the present value will disappear. Now click on the appropriate new value using the keypad and click on enter. Once you click enter the new outcome data will be calculated.
    - You will also notice a reset button on the keypad, clicking this will set the values back to their preset values.
- The range chart will provide you with an electronic calculation of velocity, torque, and maximum range for a given set of values.
    - Within this chart also have a button that will let you indicate whether anti-ice is on or off and calculates values accordingly. Today we are going to leave it off.
- The single engine level flight chart operates the same in terms of entering data values into the calculator, however in addition to the calculator there is a graphic chart.
    - Vmin and V max automatically calculated and displayed.
    - Chart buttons next to PA and Gross Weight indicates what x axis in chart will represent
    - When Gross Weight button is active (yellow) the chart on bottom represents the Vmin and Vmax values over a range of gross weights. The arrows indicated the Vmin and Vmax for the gross weight shown on the screen.

    - When Pressure Altitude button is active (yellow) chart will show Vmin and Vmax across a range of pressure altitudes. To do so select chart button next to PA box.

Final Information

- Back/fwd, history, and bookmark navigational tools remain the same and are used the same.
- Replacing the PCL navigational tool found within the checklist mode is the Calc navigational tool. Calc tool has two main functions:
    - Can take you back to the main menu for performance data (illustrate)
    - Click on close calc to close any open performance calculators. If more than one performance calculator is open at once, the currently active one will be yellow. Again, you can go back and forth between calculators by clicking on associated yellow tabs.

Instructor: Ask if there are any questions up to this point.

ALERT MODE

- Not applicable in current version
- Will be used to present conventional cautions, warnings, advisories, and eventually HUMS information to the aircrew.

NATOPS MODE

Function(s)

- Provide access to NATOPS text in format similar to paper copy.

Use of

- The main menu of the NATOPS mode contains a table of contents that lists each of the individual chapters within the paper NATOPS. Find the chapter that contains the relevant information and click on the chapter to expand it into its individual sections.
- Tree diagram is then expanded and section headings within the tree are preceded by a "-", if this button is clicked that portion of the tree will collapse and a "+" will appear before the heading. Clicking on the "+" will expand the tree again if need be. Once can't expand tree any more the actual text pertaining to selected section will appear (just as in paper NATOPS).
- Note: Some of the major sections (e.g., section 3) contain general information in addition to more specific information contained under subsections (e.g., 3.1, 3.2). Means at this point you must be careful where you click to expand or might not get the information you intended – later sections with general information will be coded differently (color).

- This mode also contains hyperlinks (in blue – clicking on them will take you to related section), schematics, diagrams, and figures – no foldouts.

<u>Navigational tools</u>

- Navigational tools such as history, bookmark, back/forward remain the same within this mode.
- Search tool is new. Clicking on the search function will allow three options: Other Docs, Index, or TOC (table of contents).
    - TOC: Takes you to a table of contents organized by individual chapters (also the main menu of the NATOPS mode).
    - Index: Takes you to an alphabetical index. Click on letter to see topics under that letter.
    - Other Docs: Contains AAW and SOP. (AAW option is still under construction.)
- Hint: May be easiest to use TOC or Index within search tool to maneuver around this mode, as back/forward tool takes you back and forward to actual text, but not to the actual tree diagrams within this mode.

Instructor: Ask if there are any questions up to this point.

<u>NOTES MODE</u>

- Electronic note pad
- Probably not that useful within scenarios will be given today.
- Allows users to take notes in electronic ink. Will use stylus.
- Secondary buttons, clear, close, save, page (create new page – plain, AAW, or SOP (later two under construction)

Instructor: At this point ask if have any questions about any of sections covered. If not explain that next they will be given some time to further familiarize themselves with the IE-NATOPS by practicing several general categories of items. Will have a couple more practice sessions after this one.

III INTERACTIVE SCENARIO BASED PRACTICE (DO NOT READ)

A. <u>FREE TIME PRACTICE/FAMILARIZATION (Do not read)</u>

This next portion of training is going to allow you to have some hands-on practice with the IE-NATOPS. Basically, I want you to take about 10 minutes and familiarize yourself/complete the actions on this checklist. If you have any questions feel free to ask.

Instructor: Hand out "Objectives During First Practice Session". Basically the sheet requires them to cover the following:

CHECKLIST MODE

- *Navigating within and between checklists*
- *Completion of a checklist*
- *Use of back/forward button*
- *Switching to the various types of checklists (EP, NP, Special procedures, etc...)*

NATOPS MODE

- *Navigating through the NATOPS chapters*
  -make sure you get to the actual text at least once
- *Use of search function using toc*
- *Use of search function using Index*

DATA MODE

- *Navigation to one of two performance charts*
- *Change the values within this chart to see how electronic calculation works*

MISCELLANEOUS

- *Use of history button to get back to a prior section of your choice*
- *Use of bookmark function (make a bookmark)*

Do you have any questions?

B. <u>PRACTICE SCENARIOS (Don't Read)</u>

DURING THIS PRACTICE SESSION WE WILL BEGIN FOLLOWING SOME OF THE PROTOCOLS THAT YOU WILL BE REQUIRED TO FOLLOW DURING THE ACTUAL SCENARIOS SO THAT YOU WILL BEGIN TO GET USED TO THEM. AT THIS POINT, WHEN YOU GO TO EACH OF THE SECTIONS THAT I ASK YOU TO, PLEASE VERBALIZE THE PATH YOU ARE TAKING AND IF COMPLETING A CHECKLIST, INDICATE THAT EACH ITEM IS COMPLETE AS YOU READ IT. FOR EXAMPLE, CLICKING ON NP, CLICKING ON TAXI CHECKLIST, STEP 1 COMPLETED, STEP 2 COMPLETED, CHECKLIST COMPLETE (MEANS YOU HAVE CLICKED ON THE "COMPLETE" BUTTON AT THE BOTTOM OF THE CHECKLIST). IT'S VERY IMPORTANT FOR US THAT YOU VERBALIZE THE PATH YOU ARE TAKING.

WE WILL DO A COUPLE OF SEARCHES WITHIN EACH OF THE MODES THAT YOU MIGHT BE REQUIRED TO USE WITHIN THE ACTUAL STUDY – STARTING WITH THE CHECKLIST MODE...

<u>SEARCHES WITHIN DATA MODE **(DON'T READ)**</u>

1) Within checklist mode, go to Normal Procedures
   - Find and open "Taxi Checklist"
   - Complete "Taxi Checklist"
2) Within checklist mode, go to Emergency Procedures
   - Go to mission equipment malfunction
   - Go to Emergency Jettison Releases

- Go to Cargo Hook Emergency Release Checklist – find but do not complete

3) Get back to Normal Procedures (*Evaluator: may use back or directly click on NP button*)
4) Use history button to get back to Emergency Procedures
5) Is the PCL button currently active? What does this tell you?
   - Go in, complete the open checklist

Now we will do a few searches within the data mode.

<u>SEARCHES WITHIN DATA MODE (**DON'T READ**)</u>

1) Within the data mode, go to Range/Level Flight Performance Menu
   - Click on Range Menu
   - Click on Maximum Range
   - Enter 3,000 PA – what does this make the velocity become?
   - Reset all functions…
   - Return to main menu for data mode (use calc function or back button)
2) Within the data mode, go to Emergency Operation Menu
   - Click on Ability to Maintain Level Flight
   - Change x axis to reflect Gross Weight or PA (*whichever not currently the x axis*)
   - Enter the following new values: PA=3,000 and WT=16,000
   - Read off the corresponding values calculated
   - Close all calculators

During the actual study you will be timed in terms of how long it takes you to access various sections of the IE-NATOPS. As such, within the last couple of searches that we are going to do, you will notice that on the last item to be completed within each search I will ask you to let me know when you are done. This is so you get used to letting us know when you have reached the answer or piece of information you are looking for because within the actual study, once you have found the final answer and say you are done is when we will stop the clock. Remember to verbalize your path.

Next, we will perform a few searches within NATOPS mode.

Searches within NATOPS mode (*don't read*)

1) Within the NATOPS mode, use the Table of Contents (TOC) to go to "Systems" Chapter
   - Click on "Electrical Systems"
   - Click on "AC Electrical Systems"
   - Click on the hyperlink, and find information contained within.
2) Return to main NATOPS menu (*use either search function or back button*) and let me know when you are there.

3) Within the NATOPS mode, use the index function to Main Landing Gear and information contained within
   - Scroll down to bottom of information so will see schematic/table, when you have reached the end let me know.
4) Get back to main menu using whatever didn't use before (Search function or back button) and let me know you are done.

The next couple of searches will cut across several of the modes.

Combination searches/Miscellaneous (*don't read*)

1) Use history function to return to the Main Landing Gear section and let me know when you have found it.

2) Go to the checklist mode, EP checklist, and find information pertaining to flight characteristics, particularly settling with power…

   - When trainee is halfway through memory items (#3) have them go to the data mode
     - Find the maximum range calculator
     - Enter PA=3,000
     - What are the new calculations?
   - Go back and complete the rest of the EP checklist (*can use back button, history button (maybe), or PCL button (easiest)*) – let me know when you are done

Do you have any questions?

G.2 First Practice Session Objectives

Objectives During First Practice Session: IE-NATOPS

DURING THE NEXT 10 MINUTES PLEASE MAKE SURE YOU GET FAMILIAR WITH EACH OF THE FOLLOWING ACTIONS. IF YOU HAVE ANY QUESTIONS, PLEASE FEEL FREE TO ASK.

CHECKLIST MODE

_____ Navigating within and between checklists

_____ Completion of a checklist

_____ Use of back/forward button

_____ Switching to the various types of checklists (EP, NP, Special procedures, etc…)

NATOPS MODE

_____ Navigating through the NATOPS chapters

-make sure you get to the actual text at least once

_____ Use of search function using toc

_____ Use of search function using Index

DATA MODE

_____ Navigation to one of two performance charts

_____ Change the values within this chart to see how electronic calculation works

MISCELLANEOUS

_____ Use of history button to get back to a prior section of your choice

_____ Use of bookmark function (make a bookmark)

Appendix H. Experiment 1 — Experimenter-Directed Searching

H.1 Final Timed Practice Session – IE-NATOPS

***Evaluator: In addition to participant saying stop when search is complete you also should say stop because the timer will be primarily looking to you.*

THIS IS THE FINAL PRACTICE SESSION AND DURING THIS SESSION WE WILL TIME YOUR SEARCHES TO GET A TYPE OF BASELINE AND ENSURE THAT YOU ARE COMFORTABLE WITH USING THE IE-NATOPS. AS WELL AS WE WILL BE TIMING YOUR SEARCHES DURING THE ACTUAL STUDY THIS WILL BEGIN TO GET YOU USED TO THE PROCEDURE. PLEASE REMEMBER TO:

- *VERBALIZE THE PATH YOU ARE TAKING – INCLUDING AS YOU COMPLETE EACH STEP OF THE CHECKLIST AND WHEN YOU HAVE COMPLETED THE ENTIRE THING (HIT COMPLETE BUTTON). IT'S VERY IMPORTANT THAT YOU GET IN THE HABIT OF VERBALIZING YOUR PATH BECAUSE DURING THE ACTUAL STUDY THERE WILL BE TIMES WHEN WE WILL HAVE TO PROVIDE YOU WITH UPDATES – THESE ARE CUED BY WHEN YOU REACH A CERTAIN POINT (HENCE THE VERBALIZATION).*
- *AGAIN, YOU WILL NOTICE THAT ON THE LAST ITEM TO BE COMPLETED WITHIN EACH SEARCH I WILL ASK YOU TO LET ME KNOW WHEN YOU ARE DONE. THIS IS SO YOU GET USED TO LETTING US KNOW WHEN YOU HAVE REACHED THE ANSWER OR PIECE OF INFORMATION YOU ARE LOOKING FOR BECAUSE WITHIN THE ACTUAL STUDY, ONCE YOU HAVE FOUND THE FINAL ANSWER AND SAY YOU ARE DONE IS WHEN WE WILL STOP THE CLOCK.*

Search #1

- Within the checklist mode, go to Normal Procedures
  - Go to "Start Checklist" and click on
  - Expand "Start Checklist"
- Go to "Systems Check" and complete all relevant checklists, including "Cargo Hook Operational" checklist. (*Note to evaluator: within this first checklist there is a hyperlink that takes them to a second checklist, should complete both checklists*).
- Return to the main menu for Normal Procedures and let me know once there (***STOP CLOCK***)

Search #2

- Use the History function to find "Flight Characteristics"
- Return to Emergency Procedures main menu and let me know once there (***STOP CLOCK***)

Search #3

- Within the checklist mode, go to Emergency Procedures
  - Go to "Sonar Malfunction"
    - Go to "Sonar"
    - Go to "Sonobuoy lithium battery venting" checklist, including the link to "Smoke and Fumes Elimination. " (*Note to evaluator: This checklist has a hyperlink to checklist entitled "Smoke & Fumes Elimination."*)
    - Complete all relevant checklists
- Within checklist mode, go to Reference Data Section
  - Go to "Engine Limits"
    - Click on "Engine Starter Limits" and once within the checklist scroll to the bottom and complete
  - Make sure all checklists are completed and closed
- Return to Emergency Procedures main menu and let me know (***STOP CLOCK***)
- How can you double check to make sure all checklists have been completed/are closed?

Search #4

- Go to NATOPS mode
  - Go to the "Avionics" section
    - Open "Mission Avionics"
- Use Search function to find "Aircrewman Only Brief" (*Evaluator: Easiest to use index*)
  - Scroll to the bottom of "Aircrewman Only Brief" and let me know when there (***STOP CLOCK***)

Search #5

- Go to the main menu for the NATOPS mode (TOC) (*Evaluator: Easiest to use Search –TOC*)
- Go to "Aircraft Operating Limitations"
  - Go to Weight Limitations
  - Go to Weight Limits (*Evaluator: As soon as trainee gets here go to next step*)
- Go to main menu for Data Mode
  - Go to emergency operations menu
    - Go to ability to maintain level flight, single engine
      - Change the Wt to 17,000 and make Wt the "x" axis
      - What are the new values?
  - Close the calculator
- Return to main menu of NATOPS mode (TOC) and let me know when you are there (***STOP CLOCK***)

Search #6

- Within checklist mode, go to "Emergency Procedures"
- Go to section pertaining to "Warning, caution, advisory light"

- Find Advisory Light section and click on
    - Find "Search Light On" section and click on (*Evaluator: Once here proceed*)
- Go to NATOPS mode to find further information on Search Light
  - *Evaluator: Easiest way is to use Index function, again once found move on*
- Go to main menu for Data Mode
  - Find "Range Level Flight"
    - Click on "Range"
      - Click on "Max Range"
        - Set Gross Weight =17,000
        - What are the new values
      - Close calculator
- Use History Function to get back to Main Menu for Data Mode and let me know when you are there (***STOP CLOCK***)

Ask if there are any final questions.... If not this concludes our training session.

<u>H.2 Final Timed Practice Session – Paper NATOPS</u>

***Evaluator: In addition to participant saying stop when search is complete you also should say stop because the timer will be primarily looking to you.*

Before we begin the actual study in which you use the paper NATOPS to find certain information we will do a couple of practice searches to get a type of baseline and give you some practice on the procedures that we will be using.

During these practice searches, we will begin following some of the protocols that you will be required to follow during the actual scenarios so that you will begin to get used to them. At this point, when you go to each of the sections that I ask you to, please verbalize the path you are taking and if completing a checklist, indicate that each item is complete as you read it. For example, clicking on NP, clicking on taxi checklist, step 1 completed, step 2 completed, checklist complete (means you have clicked on the "complete" button at the bottom of the checklist). It's very important for us that you verbalize the path you are taking.

During the actual study you will be timed in terms of how long it takes you to access various sections of the NATOPS. As such, within the last couple of searches that we are going to do, you will notice that on the last item to be completed within each search I will ask you to let me know when you are done. This is so you get used to letting us know when you have reached the answer or piece of information you are looking for because within the actual study, once you have found the final answer and say you are done is when we will stop the clock. Remember to verbalize your path.

Search #1

- In the PCL go to Normal Procedures section/tab
  - Find the Start Checklist
  - Complete the "Systems Check" checklist
    - Including Cargo Hook Operational Checklist
- *(Note to evaluator: within the "Systems Check" checklist there is a hyperlink that takes them to a second checklist "Cargo Hook Operational", should complete both checklists).*
- Close the PCL once you have completed both checklists.

Search #2

- In NATOPS go to the chapter on Emergency Procedures
  - Find section on "Flight Characteristics" and let me know when you have found this section
- Close NATOPS (***STOP CLOCK***)

Search #3

- In the PCL go to the Emergency Procedures section
  - Find "Sonar Malfunction"
    - Find section on "Sonar"
    - Find and complete "Sonobuoy lithium battery venting" checklist, including the link to "Smoke and Fumes Elimination." (*Note to evaluator: This checklist has a hyperlink to checklist entitled "Smoke & Fumes Elimination."*)
    - Complete all relevant checklists
- Now go to the Reference Data section within the PCL.
  - Find "Engine Limits"
    - Find and complete "Engine Starter Limits" checklist
- Return to the beginning of the Emergency Procedures section and let me know when you are there (***STOP CLOCK***)

Search #4

- Within NATOPS find the Avionics Chapter
  - Find the "Avionics" section
    - Find "Mission Avionics"
- Find section pertaining to "Aircrewman Only Brief" (*Evaluator: Easiest to use index*)
  - Find the last step in "Aircrewman Only Brief" and then close NATOPS (***STOP CLOCK***)

Search #5

- Using the menu in NATOPS find "Aircraft Operating Limitations"
  - Find section pertaining to "Weight Limitations"
  - Find section pertaining to "Weight Limits" (*Evaluator: As soon as trainee gets here go to next step*)
- Find performance charts within NATOPS

    - Find “Emergency Operations”
        - Find “Ability to Maintain Level Flight, Single Engine” chart
            - If your GW is 17,000
            - PA=2,000
            - OAT=20 degrees Celsius
            - Torque=109%
            - What are Vmin and Vmax values?
    - When finished calculating close NATOPS. (***STOP CLOCK***)

Search #6

- In PCL find “Emergency Procedures” section
- Go to section pertaining to “Warning, caution, advisory light”
    - Find Advisory Light section
        - Find “Search Light On” section (*Evaluator: Once here proceed*)
- Go to NATOPS to find further information on Search Light
    - *Evaluator: Easiest way is to use Index function, again once found move on*
- Find performance chart associated with Range of Level Flight in NATOPS
        - Maximum Range Chart
            - Set Gross Weight =17,000
            - PA=3000
            - Fuel=1090
            - Torque? No, but if yes 109%
            - What are the new values
- Close NATOPS when done (***STOP CLOCK***)

Ask if there are any final questions…. If not this concludes our training session.

Appendix I. Experiment 2 — Self-Directed Searching

I.1 Instructions

INFORMATION TO BE READ BEFORE BEGIN ACTUAL STUDY

Now we are going to begin the actual study. The procedure for each scenario is twofold. First, we will hand you a scenario and after reading through it we will ask you to walk us through what you would do to solve the problem/questions asked if you were actually in the cockpit flying. For example, within the actual aircraft you may not break out the NATOPS very often or may pull out the PCL once the immediate danger has passed. After you have told us how you would handle solving the problem if within the actual aircraft, we will ask you to go through and actually show us the procedure(s) that you would use to look up the required information in the NATOPS, IE-NATOPS, or PCL. I imagine the best way to look at this second part is as if you were participating in an open-book annual NATOPS check. So within the second part of this procedure things may seem somewhat artificial. During the portion of the procedure where we are requiring you to actually find the information within the PCL, NATOPS, etc. The protocols that you will be asked to follow are similar to those during your training:

- As you will be timed, tell us when you are ready to start.
- Again verbalize your path and as you are completing checklists read them out.
- Let us know when you have completed your search and found the final piece of information that will allow you to answer all the relevant questions or actions requested – at this time we will stop the clock.

Within the scenarios you should assume unless we tell you otherwise that the information given within the scenario is all the information you currently have access to. From time to time we may provide you with verbal information/updates as you go through some of the required checklists – this is why it is so important that you verbalize the path you are taking and the steps that you are doing in completing the checklists.

I.2 IE-NATOPS Evaluation Scenarios

Scenarios

1. Current Aircraft Profile:	Aircraft:	SH-60F
	Heading:	325
	Altitude:	1500 ft
	Airspeed:	~128 KIAS
	Available Fuel:	1690 lbs.
	Current Fuel Consumption Rate:	1088 lbs./hr
	Current Position from Destination:	80 NM SE
	Aircraft Gross Weight:	15500 lbs.

Narrative:

You're already in flight on a VFR cross-country training flight from airport A to airport B. You are currently 80 NM SE from your destination (as shown above). You're scheduled to attend an air show at Airport B the following day. You should be able to make it to your destination before it goes IMC, however, you decide to look for an alternate just in case. The only nearby airport (airport C) that can provide the required fuel is 56 NM farther from your current position than airport B. You call in for a weather update for your destination. The controller reports that the cold front is moving in faster then forecasted, and that airport B will be going IMC for an unspecified amount of time prior to your arrival. Airport C will remain VFR for the duration of the flight; however, you will go IMC above 3000 ft. In addition, anti-ice is off. Can you make it to airport C without going below the minimum planned fuel requirement, or will you need to re-file an IFR flight plan for airport B? Let me know when you have found the answer.

2. Current Aircraft Profile:	Aircraft:	SH-60F
	Heading:	275
	Altitude:	2000 ft
	Airspeed:	~127 KIAS
	Available Fuel:	800 lbs.
	Current Fuel Consumption Rate:	1100 lbs./hr
	Current Position from Destination:	20 NM SE
	Aircraft Gross Weight:	16500 lbs.

Narrative:

You're approaching the first refueling stop on a cross-country training flight. An unexpected strong head wind has delayed your arrival and increased your fuel consumption so you need to land as soon as possible before going below the minimum planned fuel requirement. The weather is beginning to close in from the north so you contact the controller for a weather update. The controller informs you that the airfield is going IMC. Looking at the sectional you see an airport 10 NM south of your current position. You contact that airfield for weather and available services. The controller says the airfield is VFR and that the only fuel they provide is JP-4/ JET B. Can this fuel be used, and, if so, what restrictions/considerations come with it? Let me know when you have found the answers to both questions

3. Current Aircraft Profile:	Heading:	275
	Altitude:	1500 ft
	Airspeed:	~128 KIAS
	Available Fuel:	1690 lbs.
	Current Fuel Consumption Rate:	1088 lbs./hr
	Aircraft Gross Weight:	15500 lbs.

Narrative:

You've taken off from the ship to conduct SAR training. One hour into the mission you detect smoke in the cockpit from an unknown electrical source. The flight back to the nearest ship will take approximately 20 minutes. You immediately head to the nearest ship. Perform the appropriate procedures and isolate the source of the smoke. Let me know when you have isolated the source of the smoke and performed appropriate procedures.

4. Current Aircraft Profile:	Heading:	275
	Altitude:	3000 ft
	Airspeed:	~128 KIAS
	Available Fuel:	4000 lbs.
	Current Fuel Consumption Rate:	1050 lbs./hr
	Aircraft Gross Weight:	16500 lbs.

Narrative:

You've just completed some SAR training and are returning to the ship. You're about 30 minutes from the ship when the Ng begins to drop. It goes below 55% and the #1 ENG OUT caution light illuminates. Ng goes to zero, however, Nr and all other indicators for the #1 and #2 engines are reading normal. No vibrations are indicated. Can the alternator be the cause of the problem? (Find reference in NATOPS). Are there any procedures associated with this problem? (Refer to NATOPS as required). Let me know when you have found the answers to both questions.

5. Current Aircraft Profile:	Aircraft	SH-60F
	Heading:	275
	Altitude:	On the Ground
	Airspeed:	0 KIAS
	Available Fuel:	4000 lbs.
	Current Fuel Consumption Rate:	0 lbs./hr
	Aircraft Gross Weight:	16500 lbs.
	OAT:	20 °F

Narrative:

It is 0600, and you are going on a training flight. It is the first flight of the day for this aircraft. You've already completed the pre-start and systems checks and are about to begin starting engines checklist. Find this checklist and read through procedures as if you where in the cockpit starting the #1 engine. Evaluator will provide any anomalous systems indications that may arise, otherwise assume all indications are reading normal during systems check. Complete the checklist for engine #1 before answering the following question. Are environmental factors the cause for the possible anomalous

indication? Find the NATOPS reference that discusses this indication and let me know when you have found it.

6. Current Aircraft Profile:

Aircraft:	SH-60F
Heading:	360
Altitude:	1500 ft
Airspeed:	~124 KIAS
Available Fuel:	2000 lbs.
Current Fuel Consumption Rate:	1080 lbs./hr
Aircraft Gross Weight:	16500 lbs.
OAT:	45 ° F

Narrative:

After an hour of SAR training you begin to experience low-frequency lateral vibration in the aircraft. All systems indicators are reading normal. 30 minutes later the vibrations are beginning to increase. You decide to return to ship. As you turn the aircraft you notice increased vibration, slight fluctuations in your Np/Nr, and slight pilot induced oscillations. All other systems indicators are reading normal. What is the suspected main rotor malfunction? Find information on malfunction in NATOPS. Go through emergency procedures as required. Let me know when you have completed this scenario.

7. Current Aircraft Profile:

Aircraft:	SH-60F
Heading:	090
Altitude:	1500 ft
Airspeed:	~124 KIAS
Available Fuel:	1600 lbs.
Current Fuel Consumption Rate:	1080 lbs./hr
Aircraft Gross Weight:	16500 lbs.
OAT:	10 ° C

Narrative:

You've completed the day's mission and are returning to the ship. You're about 20 minutes out when you hear very muffled explosion like sounds in the rear. You immediately check your systems instruments for anomalous indications. You detect a rapid increase in your #1 TGT and decrease in #1 Ng. What is the problem? Locate the appropriate procedures and perform. Once the situation has been stabilized, maintain level flight at 1500 ft for remainder of flight back to ship. What are your Vmin and Vmax readings at this point? (Use Single Engine Level Flight (SELF) Calculator if using the PC or the chart if using the NATOPS manual.)

8. Narrative:

You are on a return flight back to your home base when the Communication System Controller (CSC) fails. The automatic CSC failure backup mode becomes enabled. Which internal and external communications functions become available in this mode for all crew stations? Are these secure communications? Do all crew stations have external communication capabilities? Use NATOPS to obtain information. Using the Communication System Block Diagram, identify the systems that interact with the Communication System Control (CSC) by pointing to them in the diagram. Let me know when you feel you have all the answers to the questions posed in this scenario.

9. Current Aircraft Profile:

Aircraft:	SH-60F
Heading:	020
Altitude:	1500 ft
Airspeed:	~124 KIAS
Available Fuel:	4000 lbs.
Current Fuel Consumption Rate:	1080 lbs./hr
Aircraft Gross Weight:	16500 lbs.

Narrative:

You've taken off from your ship and are about 15 minutes into the flight when the controller instructs you to turn left to 270 and climb to 3000 ft. You immediately place the aircraft into a climbing left turn, when you suddenly get #1 and #2 CONV, AC ESS BUS OFF, AFCS DEGRADED, and STABILATOR caution lights illuminated. Identify the emergency and perform the appropriate procedures. Will the stabilator automatic mode be enabled in this condition? Let me know when you have answered this question and performed the actions required by the scenario.

10. Narrative:

You've just completed the first leg of a combined cross-country training/cargo transport flight, and have just landed at a small airport for re-fueling. Your aircraft is parked on a soft grassy field with a heading of 180. With the cargo and a full load of fuel the aircraft weighs approximately 19,000 lbs. Winds are 270/15 gusting to 20. With all this in mind you slowly pick the aircraft up to a hover. Suddenly the nose of the aircraft begins to yaw right. You apply more left pedal, but the yaw continues. What is happening to the aircraft and what are the factors that can contribute to this situation? Find the information in NATOPS. Let me know when you have found the answer to these questions.

Appendix J. Summary Statistics

Table J-1. Summary Statistics for Key Study Variables

	Mean	Std. Dev.	N
Search Time			
Practice1: Paper	125.43	60.75	7
Practice1: Elec.	108.71	36.34	7
Practice2: Paper	47.43	31.31	7
Practice2: Elec.	15.43	6.90	7
Practice3: Paper	91.29	31.54	7
Practice3: Elec.	57.86	11.22	7
Practice4: Paper	72.29	28.89	7
Practice4: Elec.	29.43	2.37	7
Practice5: Paper	119.00	18.06	7
Practice5: Elec.	53.86	5.21	7
Practice6: Paper	182.14	88.60	7
Practice6: Elec.	74.00	10.02	7
Avg. Practice: Paper	106.26	21.71	7
Avg. Practice: Elec.	56.55	6.12	7
Process Time			
Scenario1: Paper	196.75	63.87	4
Scenario1: Elec.	79.00	18.17	4
Scenario2: Paper	49.00	1.41	2
Scenario2: Elec.	104.33	52.33	6
Scenario3: Paper	122.25	49.09	4
Scenario3: Elec.	45.00	9.06	4
Scenario4: Paper	150.50	137.89	2
Scenario4: Elec.	290.67	177.48	6
Scenario5: Paper	258.75	205.37	4
Scenario5: Elec.	208.75	81.39	4
Scenario6: Paper	102.25	51.91	4
Scenario6: Elec.	110.00	28.78	4
Scenario7: Paper	257.33	61.05	6
Scenario7: Elec.	191.50	91.22	2
Scenario8: Paper	177.25	62.78	4
Scenario8: Elec.	227.75	50.22	4
Scenario9: Paper	171.33	77.20	6
Scenario9: Elec.	205.00	57.98	2
Scenario10: Paper	208.25	77.20	4
Scenario10: Elec.	204.50	159.31	4
Avg. Scenario: Paper	180.83	49.39	8
Avg. Scenario: Elec.	166.58	69.97	8

Table J-2. Correlations Between Demographic Variables and Key Study Variables

	Rank	Age	Months in squadron	Time in service (months)	# of deploymts	Time in present assignmt (months)	Time in previous assignmt (months)	Aircraft Hours	Approx. time in H60F/last 30 days	Approx. time in H60F/last 60 days	Approx. time in H60F/last 90 days
Search Time											
Paper	-.215	-.047	-.336	.331	.093	-.250	-.163	-.451	.038	.038	-.194
Electronic	.581	.460	-.573	-.116	.281	.065	.691	.560	-.627	-.280	-.260
Process Time											
Paper	.218	-.052	-.205	-.083	-.113	.215	-.270	.104	-.313	-.177	-.252
Electronic	-.175	.124	.223	-.100	-.124	-.298	.265	.251	-.189	-.033	.100

	Approx. time in H60H/last 30 days	Approx. time in H60H/last 60 days	Approx. time in H60H/last 90 days	Approx. total time in H60F Sim (hrs)	Total time in Rotary wing (hrs)	Total flight time (hrs)	Approx. hrs of use of PC per week	Approx hrs of use PDA per week
Search Time								
Paper	.892*	.357	.424	.514	-.398	-.377	.344	-.049
Electronic	-.608	-.725	-.575	-.595	.492	.474	-.190	.093
Process Time								
Paper	-.121	-.402	-.360	-.378	.288	.325	.193	-.122
Electronic	-.504	-.074	.011	.813*	-.044	-.069	-.523	.231

*** = p<.05**

Appendix K. Ancillary Questionnaire Analyses

Additional analyses were performed to address potential differences on the survey questions as a function of specific grouping variables obtained from the demographic data. The following category variables were examined:

1) rank—LT vs. LCDR,
2) age—less than or equal to 30 years vs. greater than 30 years,
3) time in service—less than or equal to 105 months vs greater than 105 months,
4) total hours in the H-60F—less than or equal to 600 hours vs. greater than 600 hours,
5) approximate time in the H-60F in the last 90 days—less than or equal to 15 hours vs. greater than 15 hours,
6) approximate time in the H-60F simulator—less than or equal to 100 hours vs. greater than 100 hours,
7) total time in rotary wing—less than or equal to 1500 hours vs. greater than 1500 hours, and
8) total flight time—less than or equal to 1600 hours vs. greater than 1600 hours.

Note that with the exception of rank (there was little variability here — participants were either LT or LCDR), the criteria for determining the two groupings for each category was based on median values for each category. That is, in most cases, 50% of the participants were in each grouping (e.g., for the age category, half of the participants were less than 30 years, while the other half were greater than 30 years). Traditional t-tests for independent groups were conducted on each of these categories for the particular groups that were developed. Each of these different categories will now be examined separately.

K.1 Rank

Table K-1 gives the means for each survey question as a function of rank—LT vs. LCDR. None of the t-tests were significant, indicating no difference in response to the post-experiment questions as a function of military rank.

While there were no significant differences noted, several interesting patterns seemed to emerge here when looking at rank. First, the difference in ratings between NATOPS and IE-NATOPS appear to be greater for the more senior personnel. That is, when looking at 6b, for example, it seems that the senior rank pilots rate IE-NATOPS higher on this dimension (ease of interface manipulation) than the more junior officers (1.33 for seniors vs. 1.57 for juniors). This same pattern seems evident for 7b (accessing data), 9b (finding data to resolve the scenarios), and on 10b (searching multiple sections). Juniors rated IE-NATOPS more favorably only on 8b (trouble in reading and understanding NATOPS data). Responses on 11a-f seems mixed between senior and junior personnel, while responses on 12a and 12b seem to show greater agreement on the usefulness of these functions (bookmark and performance charts) on the part of juniors compared to that of more senior officers.

Table K-1. Mean Response Rates as a Function of Rank

Item	Scoring Scale	LT	LCDR
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.00	2.33
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.00	2.33
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient 3 = too much	2.00	2.33
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.00	2.33
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.71	1.33
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	2.71	3.00
6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.57	1.33
7a. Always knew how to use paper NATOPS interface	1 = strongly agree 5 = strongly disagree	2.00	2.67
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	2.00	1.67
8a. Had no trouble reading & understanding paper NATOPS	1 = strongly agree 5 = strongly disagree	1.29	1.33
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.43	2.00
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.43	2.67
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.14	2.00
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.57	1.33
10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.57	1.33
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.14	2.33
11b. Bookmark function easy to use	1 = strongly agree 5 = strongly disagree	2.14	2.00
11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.71	1.67
11d. Tab Feature in Checklists easy to use	1 = strongly agree	1.43	1.33

	5 = strongly disagree		
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	1.43	2.33
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.43	1.67
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful	1 = strongly agree 5 = strongly disagree	2.29	3.00
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.57	2.00

K.2 Age

Table K-2 gives the means for the survey questions as a function of age—less than 30 years vs. greater than 30 years. None of these comparisons were significant, although it would appear that the younger group had greater agreement on questions 6b, 7b, 8b, 9b, but not 10b. These questions specifically address IE-NATOPS dimensions. The greatest difference in groups comes with 8b (M young = 1.20 vs. M older = 2.00). The younger group was more in agreement than the older group ($p = .06$) with the statement that they had no trouble reading or understanding the NATOPS data. This latter finding parallels what was found for junior rank pilots in the analysis of rank. This should not be surprising, as there was a strong correlation between rank and age ($r = .76$).

Table K-2. Mean Response Rates as a Function of Age

Item	Scoring Scale	<30 yrs.	>30 yrs.
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.00	2.20
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.00	2.20
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient 3 = too much	2.00	2.20
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.00	2.20
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.60	1.60
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	2.60	3.00
6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.40	1.60
7a. Always knew how to use paper	1 = strongly agree	2.20	2.20

NATOPS interface	5 = strongly disagree		
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	1.80	2.00
8a. Had no trouble reading & understanding paper NATOPS	1 = strongly agree 5 = strongly disagree	1.20	1.40
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.20	2.00
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.60	2.40
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.00	2.20
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.60	1.80
10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.60	1.40
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.20	2.20
11b. Bookmark function easy to use	1 = strongly agree 5 = strongly disagree	2.20	2.00
11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.40	2.00
11d. Tab Feature in Checklists easy to use	1 = strongly agree 5 = strongly disagree	1.40	1.40
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	1.40	2.00
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.40	1.60
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful	1 = strongly agree 5 = strongly disagree	2.40	2.50
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.60	1.75

K.3 Time in Service

Table K-3 presents the mean response rates as a function of time in service — less than 105 months represented the less experienced group, while greater than 105 months represented the more experienced group. None of the survey question comparisons were significant for this category. Again, like in the previous category of age, less experienced pilots agreed more with IE-NATOPS items (6b, 7b, 8b, 9b) than the more experienced group. Only item 10b was judged higher in agreement for the more experienced group in comparison to the less experienced group.

That these results are similar to the results reported for age is understandable in that the correlation between age and time in service is quite high ($r = .93$). It is not clear why we

do not see the same pattern for rank, since rank is significantly correlated with both age (r = .76) and time in service (r = .88).

Table K-3. Mean Response Rates as a Function of Time in Service

Item	Scoring Scale	<105 mos.	>105 mos.
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.00	2.25
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.00	2.25
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient 3 = too much	2.00	2.25
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.00	2.00
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.60	1.50
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	2.60	3.50
6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.40	1.50
7a. Always knew how to use paper NATOPS interface	1 = strongly agree 5 = strongly disagree	2.20	2.50
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	1.80	2.00
8a. Had no trouble reading & understanding paper NATOPS	1 = strongly agree 5 = strongly disagree	1.20	1.50
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.20	1.75
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.60	2.75
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.00	2.25
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.60	2.00
10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.60	1.25
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.20	2.25
11b. Bookmark function easy to use	1 = strongly agree 5 = strongly disagree	2.20	2.00

11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.40	2.00
11d. Tab Feature in Checklists easy to use	1 = strongly agree 5 = strongly disagree	1.40	1.25
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	1.40	2.00
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.40	1.50
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful	1 = strongly agree 5 = strongly disagree	2.40	2.67
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.60	1.67

K.4 H-60F Flight Time

Table K-4 gives mean response rates for the survey questions as a function of H-60F flight time — less than 600 hours vs. greater than 600 hours. Three statistically significant comparisons were noted; namely, 8a [$t(8) = 2.45$, $p = .04$], 11b [$t(8) = 2.89$, $p = .02$], and 12a [$t(8) = 2.97$, $p = .02$]. In addition, several survey questions showed levels approaching significance; 7b ($p = .09$) and 10b ($p = .07$). The significant difference on 8a indicates that the pilots with more H-60F experience (flight time) agreed more strongly with the statement that they had no trouble in reading and understanding the NATOPS data using traditional NATOPS as a source. The significant difference on 11b indicated that pilots with more experience were not as likely to agree that the bookmark function was easy to use. Finally, the difference between groups on 12a supported 11b in that more experienced H-60F pilots did not find the bookmark function as useful as less experienced H-60F pilots in the operational environment. Considering 7b, while not significant, does show that more experienced H-60F pilots agreed more with the statement that they knew what to do to the interface to access data when using IE-NATOPS; evidently, less experienced pilots were not as comfortable with this aspect. The last comparison, dealing with 10b, indicates that less experienced pilots were more in agreement than experienced pilots that it was easy to access information when it came to searching for multiple sections.

Table K-4. Mean Response Rates as a Function of H-60F Flight Time

Item	Scoring Scale	<600 hrs.	>600 hrs.
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.00	2.20
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.00	2.20
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient	2.00	2.20

	3 = too much		
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.00	2.20
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.40	1.80
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	3.20	2.40
6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.60	1.40
7a. Always knew how to use paper NATOPS interface	1 = strongly agree 5 = strongly disagree	2.40	2.00
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	2.20	1.60
8a. Had no trouble reading & understanding paper NATOPS *	1 = strongly agree 5 = strongly disagree	1.60	1.00
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.80	1.40
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.60	2.40
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.20	2.00
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.40	2.00
10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.20	1.80
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.00	2.40
11b. Bookmark function easy to use *	1 = strongly agree 5 = strongly disagree	1.60	2.60
11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.80	1.60
11d. Tab Feature in Checklists easy to use	1 = strongly agree 5 = strongly disagree	1.20	1.60
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	1.80	1.60
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.40	1.60
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful *	1 = strongly agree 5 = strongly disagree	1.75	3.00
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.25	2.00

$^{*}p < .05$

K.5 Flight Time Last 90 Days

Table K-5 shows the mean response rates for survey questions as a function of flight time acquired in the last 90 days — less than 15 hrs. vs. greater than 15 hrs. None of the comparisons were significant, but again a few showed nearly significant differences; namely, 6b (p = .07), and 12a (p = .09). This indicates that pilots with less recent experience were more likely to agree that the interface was physically easy to use (6b). Furthermore, the results demonstrate that pilots with more recent experience agreed that the bookmark was useful.

Table K-5. Mean Response Rates as a Function of Recent Flight Time

Item	Scoring Scale	<15 hrs.	>15 hrs.
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.20	2.00
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.20	2.00
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient 3 = too much	2.20	2.00
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.20	2.00
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.60	1.60
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	3.20	2.40
6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.20	1.80
7a. Always knew how to use paper NATOPS interface	1 = strongly agree 5 = strongly disagree	2.80	1.60
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	1.80	2.00
8a. Had no trouble reading & understanding paper NATOPS	1 = strongly agree 5 = strongly disagree	1.20	1.40
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.60	1.60
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	3.20	1.80
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.00	2.20
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.20	2.20

10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.60	1.40
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.60	1.80
11b. Bookmark function easy to use	1 = strongly agree 5 = strongly disagree	2.20	2.00
11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.40	2.00
11d. Tab Feature in Checklists easy to use	1 = strongly agree 5 = strongly disagree	1.60	1.20
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	2.00	1.40
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.60	1.40
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful	1 = strongly agree 5 = strongly disagree	3.00	2.00
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.75	1.60

K.6 Time in H-60F Simulator

Table K-6 shows the mean response rates as a function of total time in the H-60F simulator — less than 100 hrs. vs. greater than 100 hrs. None of the comparisons were significant, nor did they approach significance in this category.

Table K-6. Mean Response Rate as a Function of Total Time in H-60F Simulator

Item	Scoring Scale	<100 hrs.	>100 hrs.
1. IE-NATOPS training organization	1 = too loose 2 = perfect 3 = too regimented	2.20	2.00
2. Amount of IE-NATOPS training	1 = too little 2 = sufficient 3 = too much	2.20	2.00
3. Amount of IE-NATOPS practice	1 = too little 2 = sufficient 3 = too much	2.20	2.00
4. Difficulty of IE-NATOPS training scenarios	1 = too easy 2 = sufficient 3 = too complex	2.20	2.00
5. Confidence for in-flight use of IE-NATOPS	1 = very confident 5 = very uncertain	1.40	1.80
6a. Paper NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	3.20	2.40

6b. IE-NATOPS interface easy to manipulate	1 = strongly agree 5 = strongly disagree	1.40	1.60
7a. Always knew how to use paper NATOPS interface	1 = strongly agree 5 = strongly disagree	2.80	1.60
7b. Always knew how to use IE-NATOPS interface	1 = strongly agree 5 = strongly disagree	1.80	2.00
8a. Had no trouble reading & understanding paper NATOPS	1 = strongly agree 5 = strongly disagree	1.40	1.20
8b. Had no trouble reading & understanding IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.80	1.40
9a. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.80	2.20
9b. Had no trouble finding data with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.00	2.20
10a. Easy to search multiple sections with paper NATOPS	1 = strongly agree 5 = strongly disagree	2.00	2.40
10b. Easy to search multiple sections with IE-NATOPS	1 = strongly agree 5 = strongly disagree	1.40	1.60
11. For IE-NATOPS:			
11a. History function easy to use	1 = strongly agree 5 = strongly disagree	2.20	2.20
11b. Bookmark function easy to use	1 = strongly agree 5 = strongly disagree	2.00	2.20
11c. Navigation Keys easy to use	1 = strongly agree 5 = strongly disagree	1.60	1.80
11d. Tab Feature in Checklists easy to use	1 = strongly agree 5 = strongly disagree	1.40	1.40
11e. Search Feature in NATOPS easy to use	1 = strongly agree 5 = strongly disagree	1.80	1.60
11f. Performance Charts easy to use	1 = strongly agree 5 = strongly disagree	1.60	1.40
12. For IE-NATOPS:			
12a. Bookmark Function would be operationally useful	1 = strongly agree 5 = strongly disagree	2.75	2.20
12b. Performance Charts would be operationally useful	1 = strongly agree 5 = strongly disagree	1.75	1.60

K.7 Time in Rotary Wing

Table K-7 shows the mean response rates on the survey questions as a function of total flight time in rotary wing — less than 1500 hrs. vs. greater than 1500 hrs. None of these comparisons were significant; however, one of the comparisons approached significance ($p = .07$), and that was for the item associated with the benchmark function and its ease of use. In this case, pilots with less than 1500 hrs. in rotary wing rated this function as easier to use in comparison to those pilots with over 1500 hrs.